HERSCHEL-PLANCK

Planck PFM#1 Thermal test

Specification

Product Code : 200000

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ENREGISTREMENT DES EVOLUTIONS / CHANGE RECORD

Issue. Revision	DATE	§ : CHANGE RECORD	AUTHOR
0.0	15/04/2005	Draft Issue	L OUCHET
1.0	22/07/2005	First Issue considering comments from ESA and ALS	L.OUCHET
2.0	16/09/2005	Second issue considering comments from ESA and AAS	L. OUCHET

3.0	30/10/2006	Issue incorporating comments from ESA (H-P-ASP-MN-7024)
		Changes identified by change bars. Main changes are
		• Update of SCS-R performance verification objectives (§ 1.2.3)
		• Update of applicable and reference documents (§2)
		• Specific grounding rules for MLIs for PFM#1(§ 3.1.2.2.1)
		• LCL38 not used (§ 3.1.2.3)
		• Expected dissipation during test phases added (§ 3.1.2.3)
		• Addition of infrared lamps in facility (§ 4.2)
		• Chronology updated (Ph2-0001 deleted) (§ 5.1)
		• PPLM test simulation added and test duration updated (§ 5.4)
		• Test sequence updated, deletion of use of LCL38 (§ 5.5.1.4)
		• Organisation updated according to ESA presentation during PM#31 (§ 7.1)
		• Annex 4 (Thermal Control Tables) added
		• Annex 5 (Heatlift measurement procedure) added
		• Annex 6 (HK parameters) added (still TBD)
		Additional changes during signature loop
		• In § 3.1.2.2, update of horizontality requirements.
		• In § 5.5 change of LCL numbers following anomaly on SCS harness
		  o LCL's connected to SCS R are LCL's 63, 64, 65,66
		  o LCL connected to SCE R is LCL 53
		• Annex 4: introduction of TCT data for Heat Pipes heaters.
			L OUCHET

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1. TEST OBJECTIVE

1.1 Introduction

This document is the test specification for the PFM#1 testing of the Planck spacecraft. This test will be done in CSL (Centre Spatial de Liège).

This specification deals in particular with:

- Test specimen definition
- Test objectives
- Requirements towards test facilities
- Success criteria
- Input/output data

The main goals of the PFM#1 are to functionally test the Sorption Cooler Redundant (SCC-R) and to perform a thermal balance of the SVM.

1.2 Test objectives

1.2.1 SCS radiator performance

- validation of the SCS assembly thermal mathematical model (TMM) in steady state and in transient conditions

- validation of the SCS assembly thermal control design and thermal performances:

  - bed temperature level
  - bed temperature fluctuation
  - SCS heating power

- validation of the SCS thermal control flight hardware:

  - heat pipe assembly
  - heaters and thermistors location and set up

1.2.2 Planck SVM thermal balance

- validation of the SVM thermal mathematical model (TMM) in steady state and in transient conditions

- validation of the SVM thermal control S/S design and thermal performances:

  - units temperature level
  - units temperature stability
  - SVM heating power

- validation of the SVM thermal control flight hardware:
    - MLI assembly
    - heaters and thermistors location and set up

1.2.3 SCS-R performance verification

- functional validation of the SCS R with flight representative interfaces:
    - SCC radiator [260; 280K]
    - groove 3 interface [45; 60K]
    - thermal load on cold end representing the nominal heat lift. A test will be performed to estimate the SCS R cooling power.
    - presence of SCS N ensuring representativity of the mutual influence between TMU's, if any

- functional test of the regeneration sequence on the SCS-R (TBC)

1.2.4 Objectives reported to PFM#2

- The objectives related to the 3 RCS tanks (temperature level, gradient and stability) will be verified on Planck PFM#2 test.

- Any possible design modification (with possible impact on thermal performances) introduced after Planck PFM#1 test shall be validated during Planck PFM#2.

- validation of flight WU TCS design, in particular those which could not be correlated at PFM#1 level because of the lack of representativity of their MTD (such as DCCU and 4K CCU)

- Thermal cycling will be performed during Planck PFM#2.

- Microvibration verification will be performed during PFM#2. It was initially planned to perform an advanced verification on the PFM#1 but at that time, the specimen planned for this test was a complete flight satellite. Since then, to accommodate with instrument delivery dates, the test has been advanced and the specimen configuration for the PFM#1 has been descoped. In particular, w.r.t. microvibration, the microvibration source (4K cooler) is not present and the sensitive part (FPU) is also not present. The only verification which could be performed was related to the transmission of facility noise via the cone but, as the PPLM mass is not representative (telescope replaced by light tool to keep SSCE and PC3C in place) the cone frequencies are not representative. Preliminary results from the CQM test show good behaviour w.r.t. microvibration even if some NCR's were raised. However, further investigation on these NCR's requires presence of the FPU and 4K cooler, which is not the case of the PFM#1 specimen.

1.3 Requirements verified by this test

IIDB-LFI 3.1- Ch.5 [HP-LFI-REQ-0170]

IIDB-LFI 3.1- Ch.5 [HP-LFI-REQ-0160]

IIDB-HFI 3.2 - Ch.5 [HP-HFI-REQ-0220]

SRS 3.3 - Ch.5 [STHE-075 P]

SRS 3.3 - Ch.6 [SPLA-025 P]

SRS 3.3 - Ch.5 [SCVE-195 H/P]

SRS 3.3 - Ch.5 [SCVE-190 H/P]

SRS 3.3 - Ch.5 [SCVE-185 H/P]

SRS 3.3 - Ch.5 [SCVE-180 H/P]

SRS 3.3 - Ch.5 [SCVE-175 H/P]

SRS 3.3 - Ch.5 [STHE-080 H/P]

SRS 3.3 - Ch.5 [SFUN-015 P]

IIDB LFI - Sorption Cooler ICD 3.1- Ch.5 to 10 §5.7.3

IIDB LFI - Sorption Cooler ICD 3.1- Ch.5 to 10 §5.9.3

IIDB LFI - Sorption Cooler ICD 3.1- Ch.5 to 10 §5.9.3.1

2. DOCUMENTS

2.1 Applicable documents

Ref	Reference of Document	Title
AD1	SCI-PT-RS-05991 is 3.3	System requirement specification
AD2	PL-LFI-PST-ID-002 is 3.1	LFI IIDB/SCC ICD
AD3	H-P-TN-AI-0117	Planck SVM TBT thermo-couples location
AD4	H-P-1-ASP-TN-0417	Planck SVM thermal interfaces
AD5	H-P4-ASPI-IS-0042	Service module interface specification
AD6	H-P-TN-AI-0069	Heaters and thermistors description and layout
AD7	TN-CSL-PSPA-030005 TE_V2_R2	Planck thermal environment model description Mathematical model name
AD8	H-P-3-ASP-ID-1022	Planck FM1 TV test heaters EICD
AD9	H-P-3-ASP-TN-1017	Planck FM1 PLM Test Thermal Instrumentation
AD10	H-P-3-ASP-TN-1042	Thermo-optical controls on PFM1
AD11	H-P-3-ASP-TN-1046	PFM1 PPLM thermal simulation
AD12	H-P-TN-AI-0130	Planck SVM STM TV/TB Test analysis prediction

2.2 Reference documents

Ref	Reference of Document	Title
RD1	H-P-ASP-LT-6280	PPLM definition for PFM#1 cryo test
RD2	H-P-3-ASP-TN-0945	Planck PFM#1 technical description
RD3	H-P-ASP-LT-6306	SCC instrumentation
RD4	RP/CSL/PSPA/03002 Is 3.4	Planck Cryogenic Facility - Test Set-up Design Report
RD5	H-P-3-ASP-SP-0944	Flight Harness - MTD Adaptors Specification
RD6	TN/CSL/PSPA/04002 Is 1.0	RTAP &Octopussy fonctionnalités
RD9	TN/CSL/PSPA/04003 Is 1.0	Cool down and warm-up description
RD10	SCI-PT/37992	SCC TMM for Planck FM1 test prediction
RD11	H-P-3-ASP-TS-0983	Planck Sorption Cooler Functional Test in Vacuum
RD12	H-P-3-ASP-TS-0986	Planck PFM1 power ON/OFF

RD13	H-P-3-ASP-TS-1000	Planck FM monitoring
RD14	H-P-3-ASP-SP-0965	H/P Specification for Planck FM1 Vacuum Test Harness
RD15	H-P-1-ASP-SP-0027	General Design and Interface Requirements
RD16	H-P-3-ASP-TN-1034	PFM1 MLI Integration constraints
RD17		HK parameters for PFM1 test

2.3 Acronyms

AD	Applicable Document
CFRP	Carbon Fiber Reinforced Plastic
CTE	Coefficient of thermal expansion
BOL	Begin of Life
EOL	End of Life
EP	Entrance Pupil
FPA	Focal Plane Assembly
FOV	Field-of-view
PPLM	Planck Payload Module
HFI	High Frequency Instrument
HL	Heat Load
LFI	Low Frequency Instrument
LOS	Line Of Sight
LSS	Lower Structure Support
MOS	Margin of Safety
N/A	Not applicable
PA	Product Assurance
PLM	Payload Module
PR	Primary Reflector
PtV	Pic to valley
RD	Reference Document
RH	Relative Humidity
RMS	Root Mean Square
S/C	Spacecraft
SR	Secondary Reflector
TA	Telescope Assembly
TBC	To be confirmed
TBD	To be determined
WFE	Wave Front Error
Wrt	With Regards To

3. TEST SPECIMEN DEFINITION

3.1 Satellite configuration

3.1.1 Overall configuration

The configuration for the PFM#1 test is derived from the PFM configuration with the main differences

- Special configuration for the PPLM (see §3.1.3)
- Use of MTD's instead of instruments Warm Units, except for SCS.
- Use of a CQM for SCE-R instead of FM

The main items which are flight models are

- Structural elements
- Thermal control elements
- PCS, CDMS, TT&C, ACMS equipements mainly located on the (-Y/+Z) and –Y panels
- SVM harness
- Propulsion except the tanks
- TMU-N and TMU-R

The exact build standard of each element of the PFM#1is described in RD2

3.1.2 SVM configuration

3.1.2.1 Mechanical configuration

For PFM#1 test, the mechanical configuration of the SVM is similar to the flight one. The main differences are:

- No RCS tanks and RCS tanks support are present
- The solar array is replaced by a STM on which heaters are installed to simulate Sun input.
- Some equipments are replaced by MTD's as described in RD2

3.1.2.2 Thermal configuration

Heating lines configuration

- Due to gravity the switching of heaters and units on the heat pipes requires a specific sequence to be defined (see §5.3), consequently the flight thresholds of the SCS panels heating lines may be changed for the PFM#1 test

- The battery internal heaters are monitored within the threshold range [1;4°C], according to flight predictions they are never activated, a change of thresholds may be required (see AD12) in order to dissipate power in the battery and allow a correlation of the TCS.

SCC configuration

- The two flight compressors are installed but only the redundant one installed on +Y/-Z panel is activated during the test.
- the horizontality requirement on the –Y/+Z panel shall be less than 2mm/m (angle less than 0.11°) for horizontal pipes and 6 mm/m (angle less than 0.33°) for vertical pipes. This requirement is imposed by the heat pipes and covers the TMU beds horizontality requirement of ± 10°.
- as per [RD10] two different models shall be used (see annex 1) :

  - for Ph2-002 and Ph2-005 (cold/nominal TBT), BOL 270-52K nominal case TMM 345W is used which correspond to a configuration where the vertical heat pipes are at 270K, the groove 3 at 52K, and the cycle is 760 s

  - for Ph2-006 (hot TBT), BOL 262-60K hot case TMM 407W is used which correspond to a configuration where the vertical heat pipes are at 262K, the groove 3 at 60K, and the cycle is 667 s

- During regeneration (Ph2-007), the SCE remains activated to the same power as during previous SCC phases, whereas each bed is activated in a specific way (see detailed table in annex 3).During the whole phase operating temperatures shall be guaranteed by TCS
- The non-conformance H-P-200000-ASP-NC-1860 related to the SVM to SCE harness has been taken into account in this document. The impact is related to the power supply to the SCE-R and SCC-R for which the LCL numbers have to be changed. SCE-R is now powered by LCL 53 (was LCL 54) and SCE-R is now powered by LCL's 63 to 66 (was LCL's 67 to 70)

4K CCU configuration

- The 4K CCU MTD is interfering with the heaters installed on the panel, therefore additional aluminium plates are installed below the MTD baseplate to avoid any contact with the heaters, these plates are mounted on the MTD baseplate with CHOTHERM filler to ensure predictable contact conductance.
- The magnetic shield is not implemented, a MLI on the baseplate and a conductive discoupling with the mass dummy are designed to concentrate the flux to conductive contact area, the objective being to inject the dissipation on the panel, the correlation on 4K CCU can only be achieved with flight unit.
- Three test heating lines are foreseen on the MTD : 1 on the mass dummy to simulate the radiative loss and 2 on the baseplate to simulate the conductive losses on the brackets and on the straps. During the test only the baseplate ones will be powered. Due to the absence of magnetic shield, the heating line on the mass dummy will not be used.

Units not implemented

- X LGA and MGA are not mounted on PFM#1 test since the thermal environment is not representative of flight (no sun simulation).
- FOG ICU is not implemented on PFM#1 test, it is decided not to simulate its radiative effect for the following reasons:

- GEU radiative ratio (43%) will not be greatly affected since ICU is located on the side and therefore does not affect greatly the GEU view factor to the radiator.

- correlation activity will be made easier without introducing any additional MLI to simulate the ICU

- ratio conductive/radiative inside the GEU MTD is not representative of the flight behaviour (power injected on the baseplate only)

Interfaces with PLM

The interfaces with the PLM are defined in AD4 and in AD5; they are the same as in flight except for the BEU for which no wave guides are present during PFM#1 test. This is considered without impact on BEU TCS for the following reasons:

- Hot case: AD5 defines a boundary condition at 0W between BEU and wave guides, the maximum temperature are consequently not affected by the absence of the wave guides

- Cold case: The central BEU is not connected to any wave guide in flight, its minimum operating temperatures is consequently not affected by the absence of the lateral BEU wave guides.

AD5 defines a boundary condition at –15W on lateral BEUs and wave guides, the minimum operating temperature is consequently affected by the absence of the wave guides but the minimum non operating temperature can be checked during the survival mode for which no boundary condition is imposed in AD5.

Interfaces with the facility

They are described in AD7, in particular the description of the test chamber

THA/TRA/HHA thermal models will be delivered to AAS-I before the start of the test predictions

Helium tanks clocking

The position of the thermistors installed on the +/- Z tanks shall be in accordance with the AD6, in order to do so a tape will be bonded on the MLI to trace the thermistors location after MLI integration.

Test MLI

- The solar array panels (central and external) will be covered on both sides (+/-X) with 20 layer test MLI (aluminised on the outermost layer), this is done to reduce the heating power to be installed. As a consequence the solar array flight MLI will not be mounted on PFM#1 specimen

- THA/TRA/HHA will also be covered on both sides (internal/external) with 20 layer test MLI (aluminised on the outermost layer), this is done to monitor accurately the 0 flux interface.

- Three spare blankets (aluminised on the outermost layer), and three spare blankets (black on the outermost layer) were manufactured to cover the “cut to fit” activities described in the following table.

Interfaces between flight MLI and test MLI are described in RD16

BEU shim plates

The two lateral BEU MTD’s will be mounted on a 8 mm thick shim plate, this shim plates are used only for the purpose of PFM#1 test.

3.1.2.2.1 TCS hardware/software

Delta test/flight	Impact on flight hardware	Test configuration
Solar array with cut outs for 0.1K pipes and harness routing	Cuts on SA MLI	Flight MLI replaced by test MLI

No sun simulation	None	Specific test heaters (SA and LVA ring) Additional SA front side MLI
WU simulated by MTD (except SCC)	WU fillers used only once Thermistors cannot be debonded	1 of the 3 flight sets is used for PFM#1 24 thermistors are used for PFM#1 (*)
4K CCU MTD to be mounted on aluminium plates in strap ared to avoid interference with heaters installed on panel	None	Specific test fillers between MTD and plates on the 2 straps, nor plate neither filler is needed on the brackets
Lateral BEU MTD different baseplate shape w.r.t flight	None (filler design same footprint than shim plate)	Use of flight fillers
Coax to wave guides transitions	Wave guides MLI different design	Flight MLI replaced by test MLI
No bellow on PAU	None	Additional test MLI on PAU
No RAA	None	Additional test MLI on BEU
No RCS tank	None	Heating lines disabled
Heat pipes under gravity	None	Thresholds adjustments (see §5.3) Tilt on horizontal heat pipes shall be less than 2mm/m
No balancing masses	Flat MLI	Flight MLI replaced by test MLI
Missing cooler pipes	None	Specific test MLI to cover holes

(*) List of the 24 thermistors installed on WU dummies

- 6 on DPU
- 3 REU
- 3 CAU
- 3 CCU
- 3 REBA
- 3 PAU
- 3 CRU

The thermistors attrition number is consequently reduced from 30 (318 purchased – 48x3 used on Herschel – 48x3 used on Planck) to -6 (30-24). In addition, considering 6 thermistors used on Herschel STM and 8 thermistors used for Planck monitoring purpose, the deficit reaches –8.

The replacement by thermo-couples would require specific EGSE equipped with a flight simulation software, and would not allow the validation of the CDMU software on these lines. As a consequence 38 Fenwall thermistors were released from AAS-F stocks to restore a proper attrition figure (-8+38=30)

For the PFM#1 test it is agreed that relaxed grounding rules can be used for the MLIs the only goal being to prevent charging during on-ground operations. As a minimum, the following rules shall be followed:

- At least one grounding point per external blanket, daisy chaining is authorised

- In case no grounding point is easily accessible, it can be envisaged to use conductive tape to connect the grounding strap to the structure
- The bonding of each MLI blancket shall be verified. A maximum value of 1 KΩ is acceptable (w.r.t. the value of 100 mΩ specified in RD15, GDEL-120).

3.1.2.2.2 EGSE connexion

External heating power is needed for heaters implemented on the following SVM elements:

- Solar array
- LVA ring

These heaters are powered by the Thermal Regulation EGSE which have been specifically developed by Rovsing in the frame of Herschel-Planck programme. The electrical interface for these elements is described in AD8.

The following table summarises the electrical characteristics of these heaters

Test heaters	Power installed	Heater resistance	Number of heaters	Equivalent resistance
Solar array (central)	160 W (50V)	437 Ohm	28	15.6 Ohm
Solar array (external)	298 W (50V)	437 Ohm	52	8.4 Ohm
LVA ring	137 W (50V)	437 Ohm	24	18.2 Ohm

Location of the heaters on solar array and LVA ring test heating lines are provided in annex 2.

Heaters on solar array and LVA ring have the following characteristics:

- reference RS04378813KF
- resistance of 437 Ohms
- equipped with main and redundant circuits
- dimensions of 15*200 mm
- bonded with Y966 + drops of HYSOL EA 9321
- all mounted in //

In addition, heaters are implemented on the TRA, under responsibility and control or the facility. Similarly, the infra red lamps used to safeguard the satellite (see § 4.2) are power by facility EGSE.

3.1.2.3 Equipments

The build standard of equipments in the SVM is described in RD2

As not all instrument units will be present in the PFM1, they will be replaced by MTD's or CQM (only for SCE-R). In order to limit harness complexity, the MTD's will be powered from the PCDU, using the SVM flight harness plus extensions to make the adaptation between flight connectors and MTD's connectors. In order to match the power dissipation of the flight units, adaptation in the use of the MTD's had to be made such as:

- connection in series of nominal and redundant circuits
- modification of the MTD internal harness (REU)

This adaptation harness, specific to PFM#1, is described in RD5.

The Table 3-1 shows the difference between units flight dissipation and MTD's dissipation. Even is some difference in dissipations exists between MTD's and flight units due to the connection to the 28 V bus, the total dissipation per panel is respected and this allows to perform a representative thermal balance.

Unit	MTD power connected to PCDU	Flight dissipation
Z Panel		
DPU	37.3	22
Sub PF		
PAU	18.7	15
BEU central	9.3	12
BEU lateral	16.3	9
BEU lateral	16.3	11
DAE	11.2	13
TOTAL Sub PF	71.9	60
Y Panel		
REU	74.7	92
4K CDE	37.3	42.8
4K CAU	30.2	15
4K CCU	43.9	60
TOTAL Y Panel	186.1	209.8
+Y+Z Panel		
4K CRU	21.8	21
DCCU	18.7	16
REBA	37.3	41.5
FOG GEU	22.4	27
TOTAL +Y+Z Panel	100.2	105.5
TTC Panel		
XPND1 Tx+Rx	8.6+7.1	13+10
XPND2 Tx+Rx	8.6+7.1	13+10

Table 3-1

Due to the constraints linked to the MTD use, on the PFM1 a MTD unit is not connected on the same LCL as the FM unit on the FM satellite. The correspondence between LCL's number and MTD units is shown in Table 3-2.

Note: It is not planned to use the heater for "HFI 4K Capot" as its thermal representativity is not good. This means that LCL#38 should not be switched ON. The other heaters on the HFI 4K MTD (43.9 W) are connected to LCL#61. The power of 74.1 W indicated for LCL#61 corresponds to the sum of these 43.9 W plus the 30.2 W of the 4K CAU

The Table 3-3 gives the expected dissipations of the flight units during the PFM#1 test

LCL#	Flight Designation	LCL Class	Max Power LCL can Supply (W)	Connected to MTD	MTD Power Demand (W)	Operating notes
3	XPND1 Rx	FCL	28	XPND1 Rx Nominal Heater	7,1	Redundancy in MTD available but not connected to FCL
4	XPND2 Rx	FCL	28	XPND2 Rx Nominal Heater	7,1	Redundancy in MTD available but not connected to FCL
11	HFI REU Proc Nom	I	28	HFI PAU Nominal Heater	18,7	Either Nom OR Red Heater, NOT both
12	HFI REU Proc Red	I	28	HFI PAU Redundant Heater	18,7	Either Nom OR Red Heater, NOT both
13	FOG Channel 1	II	70	FOG Nominal Heater	22,4	Either Nom OR Red Heater, NOT both
14	FOG Channel 2	II	70	FOG Redundant Heater	22,4	Either Nom OR Red Heater, NOT both
23	XPND1 Tx	I	28	XPND1 Tx Nominal Heater	8,6	Redundancy in MTD available but not connected to LCL
16	XPND2 Tx	I	28	XPND2 Tx Nominal Heater	8,6	Redundancy in MTD available but not connected to LCL
27	LFI REBA Nom	II	70	LFI REBA Nom. Nominal Heater	37,3	Either Nom OR Red Heater, NOT both
28	LFI REBA Red	II	70	LFI REBA Nom. Redundant Heater	37,3	Either Nom OR Red Heater, NOT both
29	HFI DPU Nom (PHBA-N)	II	70	HFI DPU Nom. Nominal Heater	37,3	Either Nom OR Red Heater, NOT both
30	HFI DPU Red (PHBA-R)	II	70	HFI DPU Nom. Redundant Heater	37,3	Either Nom OR Red Heater, NOT both
36	HFI DCE	II	70	DCCU Nominal Heater	18,7	Redundancy in MTD available but not connected to LCL
37	HFI 4KCDE Nom (PHDC)	II	70	HFI 4KCDE Nom Nominal Heater	37,3	Redundancy in MTD available but not connected to LCL
38	HFI 4KCDE Red (PHDC)	II	70	HFI 4K Capot Nominal Heater	23,8	Redundancy in MTD available but not connected to LCL. Not used during PFM1
39	HFI REU belts 0 & 1	II	70	HFI REU Redundant Heater 1	37,3	Either Nom OR Red Heater, NOT both
40	HFI REU belts 2 & 3	II	70	HFI REU Redundant Heater 2	37,3	Either Nom OR Red Heater, NOT both
42	HFI REU belts 6 & 7	II	70	HFI REU Nominal Heater 1	37,3	Both Heater 1 AND Heater 2 ON,
43	HFI REU belts 8 & 9	II	70	HFI REU Nominal Heater 2	37,3	Both Heater 1 AND Heater 2 ON,
51	LFI DAE Power Box Nom	III	140	LFI DAE Nominal + Redundant Heater in Series	11,2	No Redundancy in MTD available
52	LFI DAE Power Box Red	III	140	LFI BEUs Nominal + Redundant Heater in Series	41,9	No Redundancy in MTD available
59	HFI 4KC Drive bus Nom	III	140	HFI 4KCRU Nominal Heater	21,8	Redundancy in MTD available but not connected to LCL
61	HFI 4KC Drive bus Red	III	140	HFI 4KCAU Nominal+Redundant Heater in Series+4KCCU Straps+brackets Nominal Heaters	74,1	No Redundancy in MTD available for CAU, Redundancy available for CCU but not connected to LCL

Table 3-2: LCL to MTD functions

	Phase 1	Phase 2-002	Phase 2-004	Phase 2-005	Phase 2-006	Phase 2-007	Phase 3-001
CDMU	35.3	35.3	35.3	35.3	35.3	35.3	35.3
ACC	31.8	30.9	30.9	30.9	30.9	30.9	30.5
STR1	OFF	13.8	13.8	13.8	13.8	13.8	13.8
STR2	OFF	OFF	13.8	OFF	OFF	OFF	OFF
CRS1	7.9	7.9	7.9	7.9	7.9	7.9	7.9
CRS2	7.9	7.9	7.9	7.9	7.9	7.9	7.9
CRS3	7.9	7.9	7.9	7.9	7.9	7.9	7.9
EPC1	8.0	8.0	8.0	8.0	8.0	8.0	8.0
EPC 2	OFF	OFF	OFF	OFF	OFF	OFF	OFF
TWT1	25.6	25.6	25.6	25.6	25.6	25.6	25.6
TWT2	OFF	OFF	OFF	OFF	OFF	OFF	OFF
PCDU	69.4	90.1	90.3	90.1	92.6	92.6	91.1
PT	0.3	0.3	0.3	0.3	0.3	0.3	0.3
SREM	OFF	2.3	2.3	2.3	2.3	2.3	2.3
SCE-R	OFF	110.0	110.0	110.0	110.0	110.0	110.0
SCC-R	OFF	345.0	345.0	345.0	407	407	407
SCE-N	OFF	OFF	OFF	OFF	OFF	OFF	OFF
SCC-N	OFF	OFF	OFF	OFF	OFF	OFF	OFF
1N-Thrusters cat bed heating	OFF	4.6	4.6	4.6	4.6	4.6	OFF
20N-Thrusters minimum heating	17.0	17.0	17.0	17.0	17.0	17.0	17.0
20N-Thrusters cat bed heating	17.0	OFF	OFF	OFF	OFF	OFF	OFF
Latch valve	OFF	OFF	OFF	OFF	OFF	OFF	OFF
MTD's							
XPND1	15.7	15.7	15.7	15.7	15.7	15.7	15.7
XPND2	7.1	7.1	7.1	7.1	7.1	7.1	7.1
FOG GEU	OFF	22.4	22.4	22.4	22.4	22.4	22.4
BEU	OFF	41.9	41.9	41.9	41.9	41.9	41.9
DAE	OFF	11.2	11.2	11.2	11.2	11.2	11.2
REBA-N	OFF	37.3	37.3	37.3	37.3	37.3	37.3
REBA-R	OFF	OFF	OFF	OFF	OFF	OFF	OFF
DPU-N	OFF	37.3	37.3	37.3	37.3	37.3	37.3
DPU-R	OFF	OFF	OFF	OFF	OFF	OFF	OFF
PAU	OFF	18.7	18.7	18.7	18.7	18.7	18.7
REU	OFF	74.7	74.7	74.7	74.7	74.7	74.7
4K-CCU	OFF	43.9	43.9	43.9	43.9	43.9	43.9
4K-CAU	OFF	30.2	30.2	30.2	30.2	30.2	30.2
4K-CDE	OFF	37.3	37.3	37.3	37.3	37.3	37.3
4K-CCR	OFF	21.8	21.8	21.8	21.8	21.8	21.8
DCCU	OFF	18.7	18.7	18.7	18.7	18.7	18.7

Table 3-3: Units dissipations during PFM1 test phases (all values in W)

3.1.3 P-PLM configuration

The PPLM part of the test specimen will be mainly composed of:

- FM cryo-structure to support the PACE
- A telescope dummy which will simulate the telescope/Cryo-structure and SCCE/FPU interfaces (FM is not available at this time because of the FM telescope cryo test campaign)

The configuration is shown in Figure 3.1-1

The telescope dummy shall simulate the cryo-structure and the SCCE interfaces. In order to:

- guarantee the CS-telescope assembly stiffness w.r.t the transport and test environment (gravity along y axis)
- avoid any other stress of the FM CS and FM PACE during cool down,

its design will be mainly composed of an invar frame and a permaglass structure which provide the adequate conductive discoupling between the invar frame and the interface simulators. The different elements of the telescope dummy will be adjustable to relax as much as possible their geometrical tolerances.

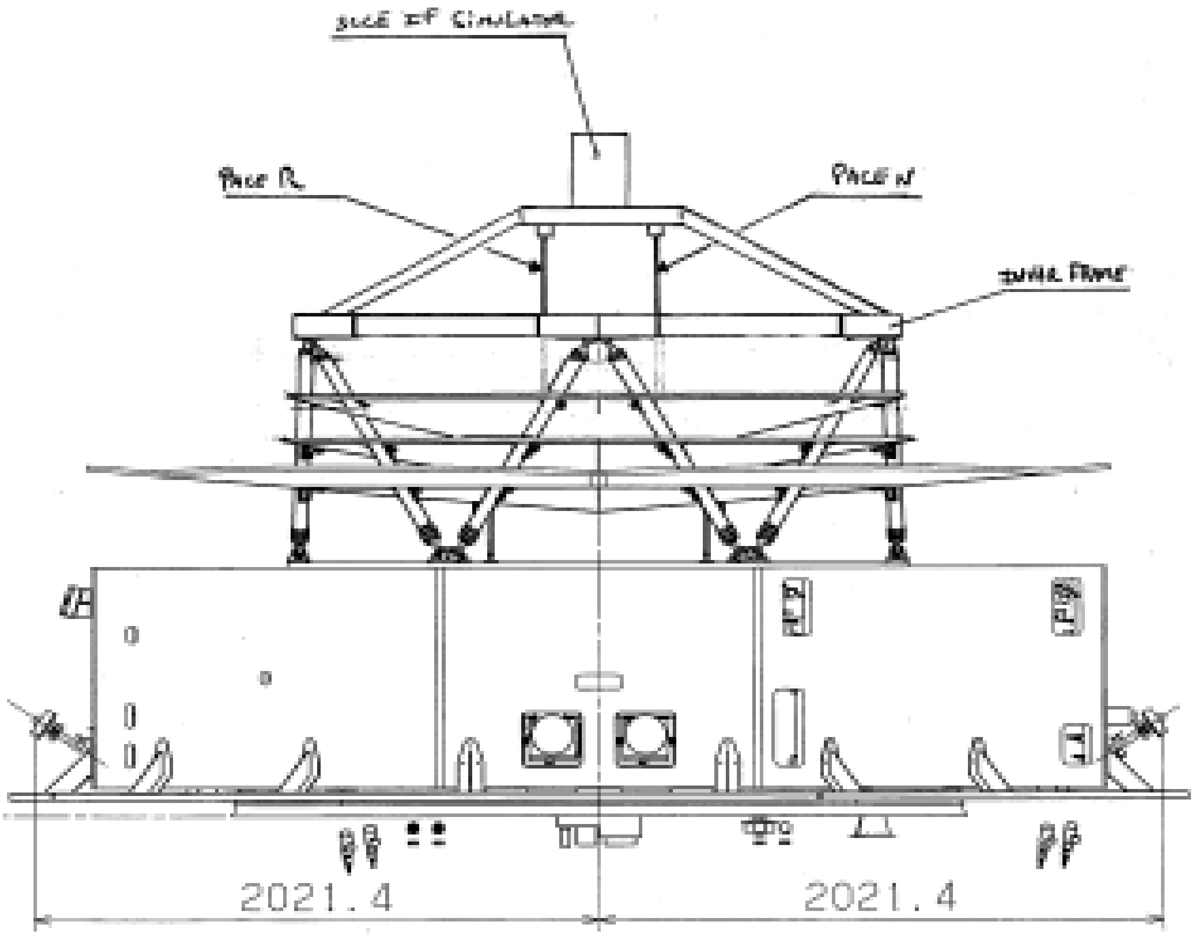


Figure 3.1-1: PPLM configuration for PFM#1

In order to verify the SCC assembly thermal control design and thermal performances test shall be performed with flight representative average power dissipation and overshoot of the Sorption Cooler. According to JPL these conditions are fulfilled when the Sorption cooler is operated with flight representative cold interface conditions:

- PC3C/Groove 3 interface temperature in the range [45K – 60K]
- SCCE environment (conductive and radiative coupling, dissipations) which allow to obtain the nominal cooling power (1W)

To reach the [45K – 60K] at PC3C/VG 3 interface, solution with passive cooling system only (i.e. without any IF with CSL test facility) has been envisaged. However, preliminary analyses have shown that the reduced surface of the radiator (about half of the nominal since the baffle cannot be mounted) is not enough to guarantee the PC3C/Groove 3 interface temperature, even if there is no dissipation for the JFET, WG, 4K and 0.1K. (decrease of about 5 to 10 K).

Consequently, the proposed solution is based on an MGSE actively cooled by a thermal strap connected to the CSL test facility. In that case, the configuration will be the following:

- Groove 3 extensions will be not mounted and PC3C/Groove 3 interface will be provided by an interface simulator which will be fixed on the telescope dummy frame. The thermal conductive coupling between the telescope frame and the interface simulator shall be minimized (2.10^{-3} W/K at operational conditions).
- Active cooling of the PC3C interface will be provided by the facility by connecting the PC3C interface by a thermal strap to a He cooled cold point inside the chamber
- [45K-60K] temperature range will be guaranteed by active control. The monitoring of the temperature level will be performed at ± 0.5 K. Such an accuracy will allow relaxing the passive part of the design. In addition, the interface temperature can be selected in the full 45K-60K range.

Note that since it is assumed that the IF temperature performance on groove 1 and 2 is not mandatory, the extensions of the groove 2 will not be mounted (simplification of the integration sequence). On the other hand, the extensions of the groove 1 shall be mounted in order to have at least one thermal shield between the SVM and the telescope dummy.

An interface plate mounted on the telescope frame with a dedicated structure will provide SCCE-FPU interface. In order to guarantee a flight representative SCCE behaviour (cooling power about 1 W), the heat load budget of the SCCE/FPU interface shall be equivalent to the FPU one. For that, the design of the interface plate and its supporting structure have to minimize as much as possible the heat loads on the interface plate and equivalent FPU heat load will be injected with active thermal control.

For this solution the design of the supporting structure shall guarantee a conductive decoupling lower than 4.10^{-4} W/K at operational conditions.

In summary, the PPLM part of the test item is composed of (see Figure 3.1-1):

- PACE-R + PACE-N
- FM cryo-struts
- FM groove 1 with its extensions
- FM groove 2 & 3 without extensions
- Telescope dummy

The telescope dummy design is presented Figure 3.1-2, Figure 3.1-3 and Figure 3.1-4. It is mainly composed of:

- An invar frame mounted on the cryo-structure
- PC3C interface simulator supported by the frame with a specific support structure made of stainless steel (to simulate the thermo-elastic behaviour) and permaglass element for thermal decoupling. The thermal conductance of this support structure is lower than 2.10^{-3} W/K at operational conditions. (see Figure 3.1-3)
- SCCE interface simulator supported by the frame with a specific permaglass support structure. The thermal conductance of this support structure is lower than 4.10^{-4} W/K at operational conditions. (see details Figure 3.1-4)
- Active thermal control:
    - ü Thermal strap between the PC3C interface simulator and the CSL facility

- Heater bonded on the PC3C interface simulator
- Heater bonded on the SCCE interface simulator

Heaters characteristics and layout are described in AD9. Electrical interfaces of the heaters to test facility are described in AD8.

The heaters used to control the PLM dummy will be powered by the so-called Thermal Regulation and Power Regulation EGSE which have been specifically developed by Rovsing in the frame of Herschel-Planck programme.

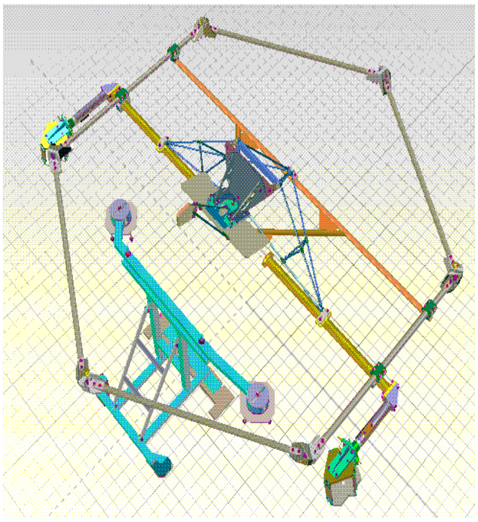


Figure 3.1-2: Telescope dummy design (overview)

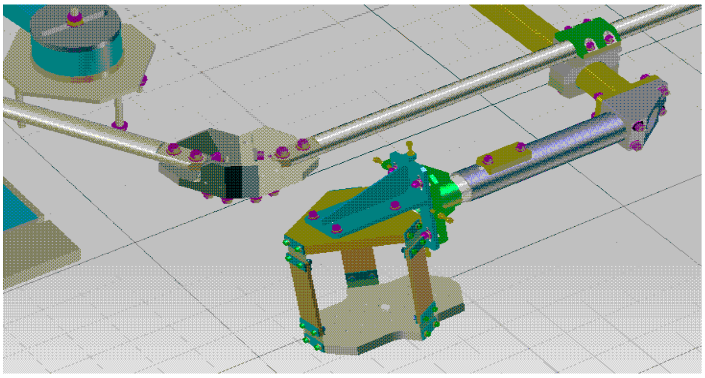


Figure 3.1-3: Telescope dummy design (PC3C interface simulator)

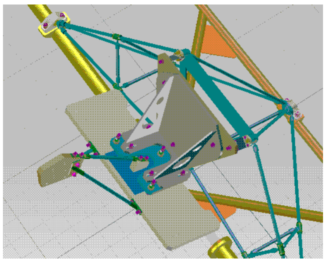


Figure 3.1-4: Telescope dummy design (SCCE interface simulator)

3.2 Instrumentation

3.2.1 SVM instrumentation

The instrumentation plan for the SVM is described in AD3.

The total number of thermocouples installed on SVM is 355, but due to facility limitation, only 196 will be connected for PFM#1.

3.2.2 PPLM instrumentation

The instrumentation plan for the PPLM is described in AD9. The total number of sensors to be acquired is

- 16 Silicon Diodes DT470
- 6 PT100 probes

4. TEST FACILITY REQUIREMENTS

4.1 Main constraints w.r.t to the facility

4.2 Test configuration

The configuration of the facility for the PFM#1 will be identical to the one used in the CQM test.

Only modification envisaged to the facility is to extend the He circuit of the Charcoal panel in the vicinity of the PC3C interface simulator, providing a cold interface at 20K (discussion on the feasibility is in progress with CSL).

Optical shield is not needed for PFM1 performance testing during test as no FPU is present. From contamination point of view, a cold point is steel needed during warm-up and optical shield could be used for this purpose following deletion of charcoal panel (replaced by cold interface to PC3C)

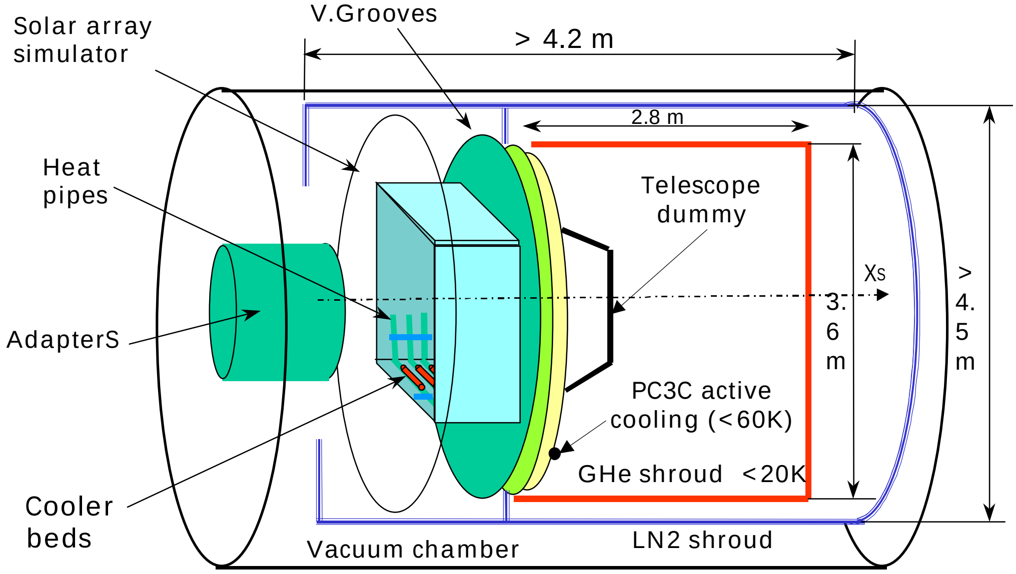


Figure 4-1: Thermal & cryogenic test configuration of Planck

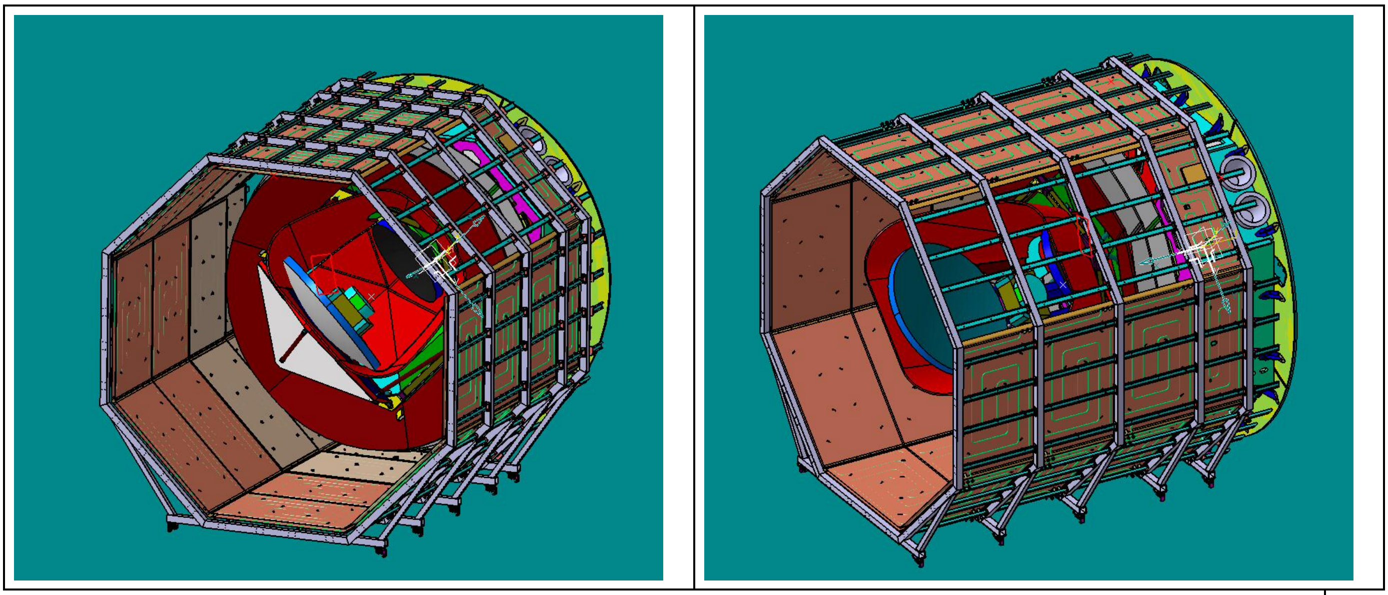


Figure 4-2: Test set-up Shrouds configuration

One critical issue is the temperature of the sorption cooler during the cold thermal balance. During this phase, the thermal control maintains the beds interface at –19°C. In case of power failure (e.g. power SCOE failure) or thermal control failure (CDMU software crash) the temperature drop of the SCC panel is fast and the SCC interface reaches its acceptance temperature (-25°C non operating) in 20 minutes. This is considered critical and so infra red lamps shall be installed inside the chamber to warm up the SCC panels in case of emergency.

The configuration is shown in Figure 4-3:

- 4 lamps in the chamber corners in front of the SCC panels
- Power of each lamp: 500 W
- Centered along X w.r.t. SVM lateral panels
- Common power supply, specific switch for each lamp
- Baffle around each lamp to direct the flux towards the SVM panels.

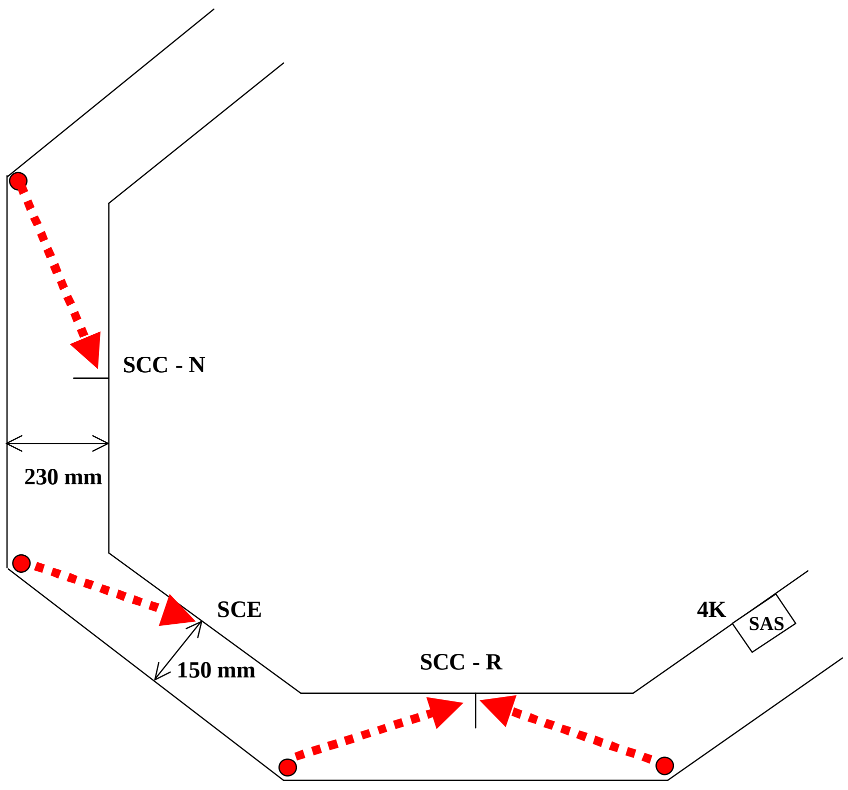


Figure 4-3: Infra red lamps configuration

4.3 Test GSE Configurations and interfaces

4.3.1 EGSE configuration

The shows the configuration of EGSE used to operate the spacecraft and for performance testing during the PFM test campaign #1.

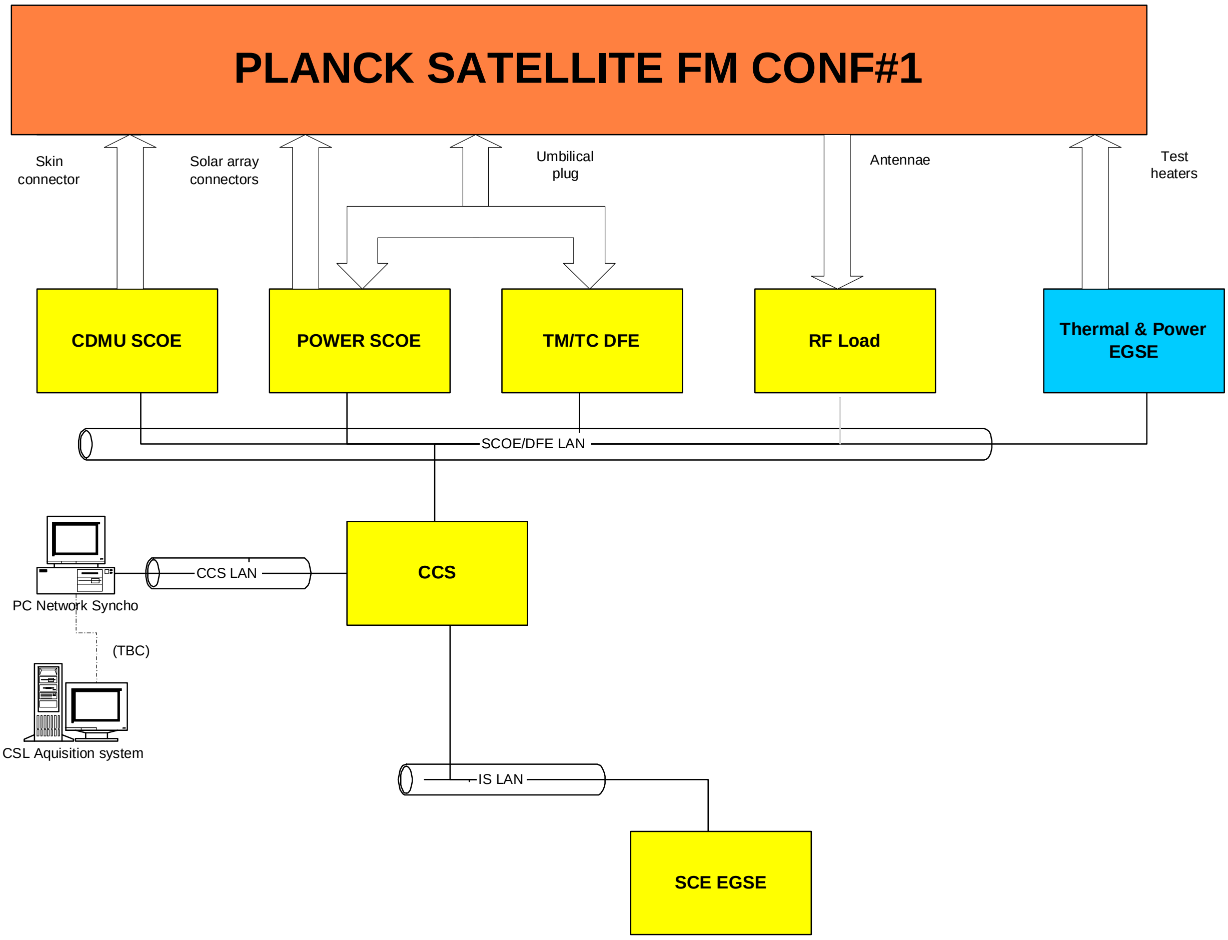


Figure 4-4: Configuration of spacecraft EGSE for PFM

The CCS controls the sequencing of the test and any stimuli required, the experiment EGSE have a passive role limited to monitoring the status of the experiments and of the test. The system level EGSE will take inputs from the satellite in the defined standard formats, build telemetry and telecommand files and the test procedures to be executed at system level. During the system level tests the experiment EGSE is required to support all the tests, the only exception to this being the abbreviated functional test.

In the flight operations phase the experiment EGSE may form part of the system used by the experiment team to analyse the experiment data.

4.3.2 Thermal & Power EGSE

A "Thermal and/or Power EGSE" will be used to obtain the requested temperature/power by injection of power (manually based on measurement done by the facility acquisition system):

- Regulation of solar array
- Telescope dummy

A "CSL Power EGSE" will be used to obtain the requested temperature/power by injection of power :

- Thermal Ring Adapter

4.4 Vacuum Chamber Interfaces

The shows the interface configuration used to operate the spacecraft and for performance testing during the PFM1 test campaign.

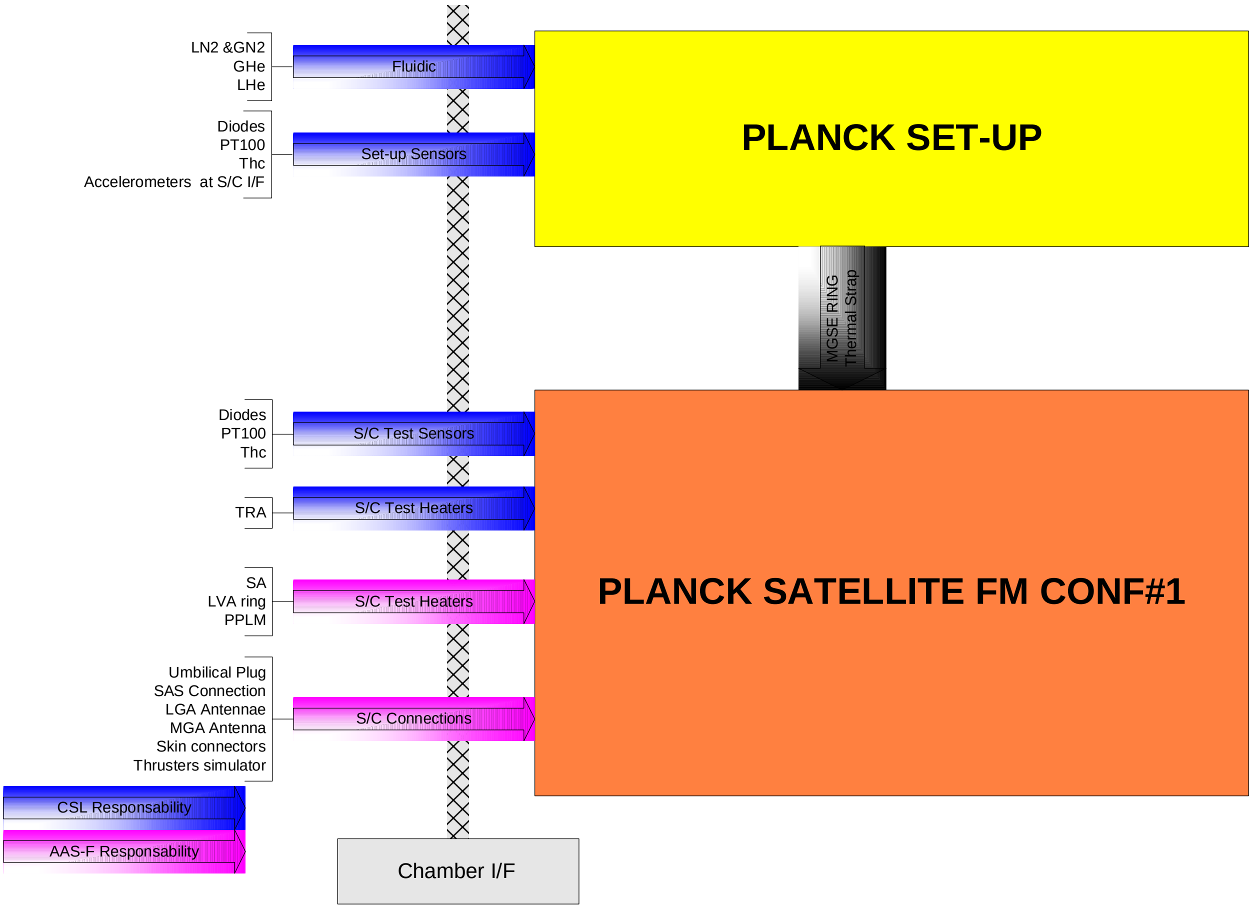


Figure 4-5: PFM1 Interface configuration

4.5 Facility Instrumentation

Major part of the information presented in this section has been extracted from RD4.

4.5.1 CSL acquisition system

The figure hereafter presents a general view of the CSL acquisition system.

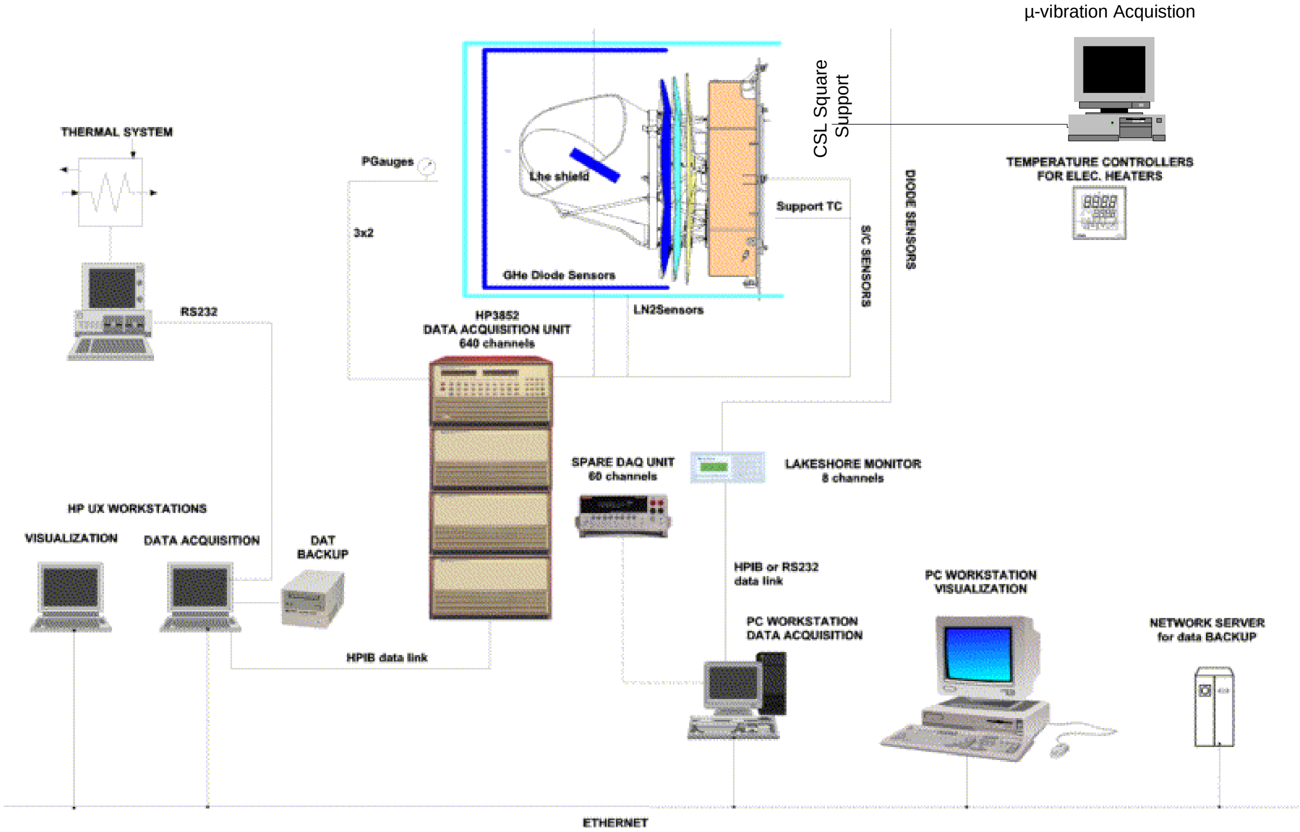


Figure 4-6: CSL acquisition Layout

The data acquisition of Focal 5 is realised by a data logger HP 3852. This data logger is connected, via internal network, to two HP9000 workstations running with industrial standard operating systems and software tools: HP-UX, X-windows, NFS, RTAP.

A second data logging system for the optical shield is realised by a Lakeshore monitor and a PC. This PC will be equipped with Agilent VEE software and a HPIB link or RS232 connected to the Lakeshore sensors.

Data backup of this PC will be done daily on CSL Servers.

A spare Keithley 2701 data logger will be added to this system with a smaller capacity (60-80 channels) to serve as a temporary backup in case of failure of the main data logger.

RTAP for the real time acquisition

- To be configured before the test
- Acquisition: (1 acq/min)
- Thermocouples T.
- Thermocouples with coefficients (client).
- PT100 4 wires.
- PT500 4 wires.
- Thermistances 2 wires.
- Sensors Cryo.
- Pressure (Membranovac & Combivac).
- Tension.
- Automatic backup on DAT tape every 24h.

Octopussy (ref RD6) for the data management

- Can be configured during test
- Maxi 6 graphs per screen (total 48 series).
- Historian online on last 24h (cache) + function 'quasi' real. time
- Historian offline Min.-Max. or average.
- Zoom.
- For the following data:
  - T° (K et °C).
  - Gradients, averages (t°).
  - Pressure (mBar).
  - Tension (V).

4.5.2 Temperature Sensors breakdown

The table here after presents the thermal instrumentation of the CSL set-up

Localisation	Type	Sensor qty	Datalogger chnl
Square support monitoring	TC-T	6	6
LN2 shrouds around PLM	TC-T	24	24
LN2 shrouds cover	TC-T	8	8
Square support regulation	PT100	2	0
LN2 shrouds around SVM monitoring	PT100	16	32
LN2 shrouds around SVM regulation	PT100	16	0

Localisation	Type	Sensor qty	Datalogger chnl
LN2 shrouds closure active shrouds	PT100	8	16
Harnesses (regulation)	PT100	4	0
piping at interface (regulation)	PT100	6	0
cold panel	PT100	2	4
Helium piping	DI	4	8
Cryopump	DI	2	4
GHe shrouds around PLM	DI	24	48
GHe shrouds around PLM gradient	DI	4	8
GHe shrouds cover	DI	8	16
LHe optical shield	DI	5	5
TOTAL		139	179

SUBTOTAL per sensor type	TC-T	38	
	PT100	54	
	DI	47	
		139	

The presents the thermal sensors localisation on He shrouds.

The presents the thermal sensors localisation on Liquid Nitrogen shrouds.

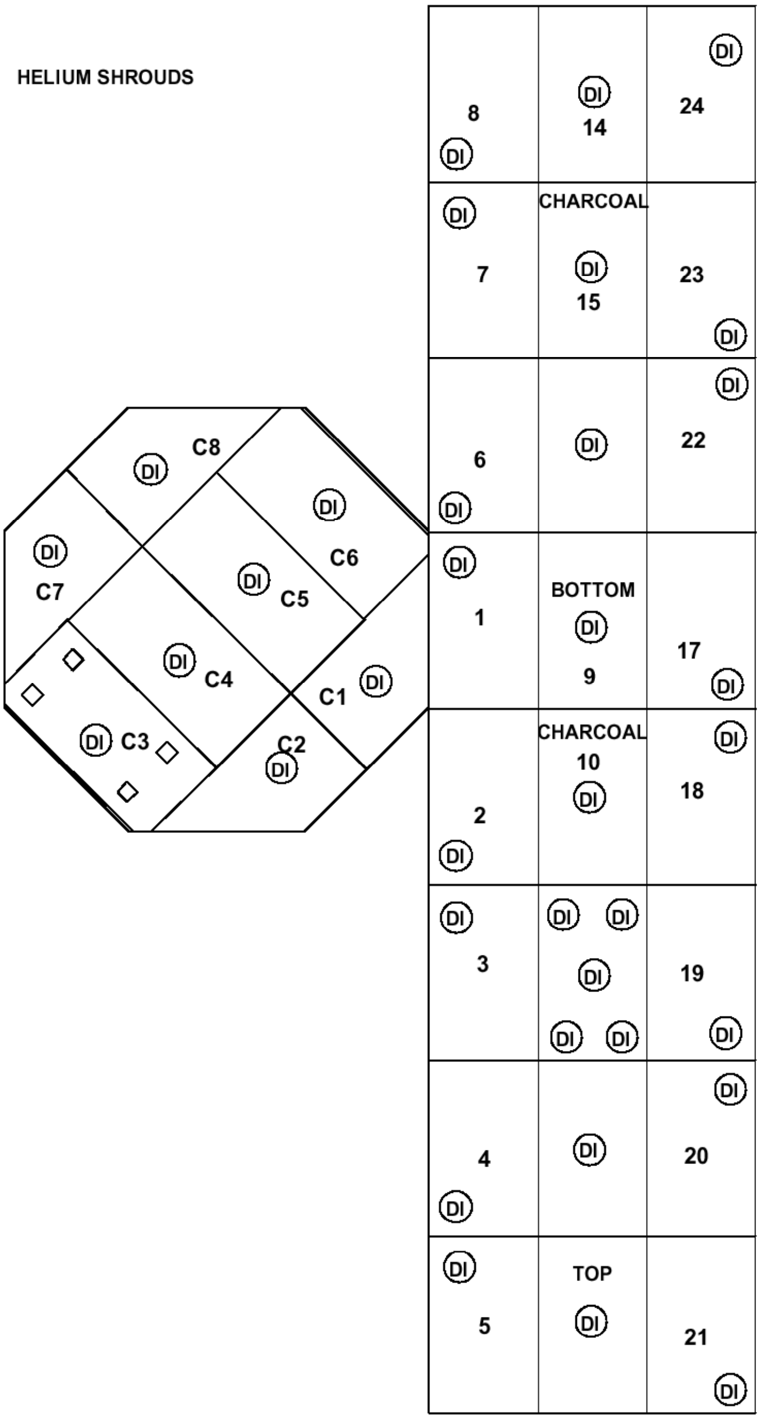


Figure 4-7: Thermal sensor localisation on He shrouds

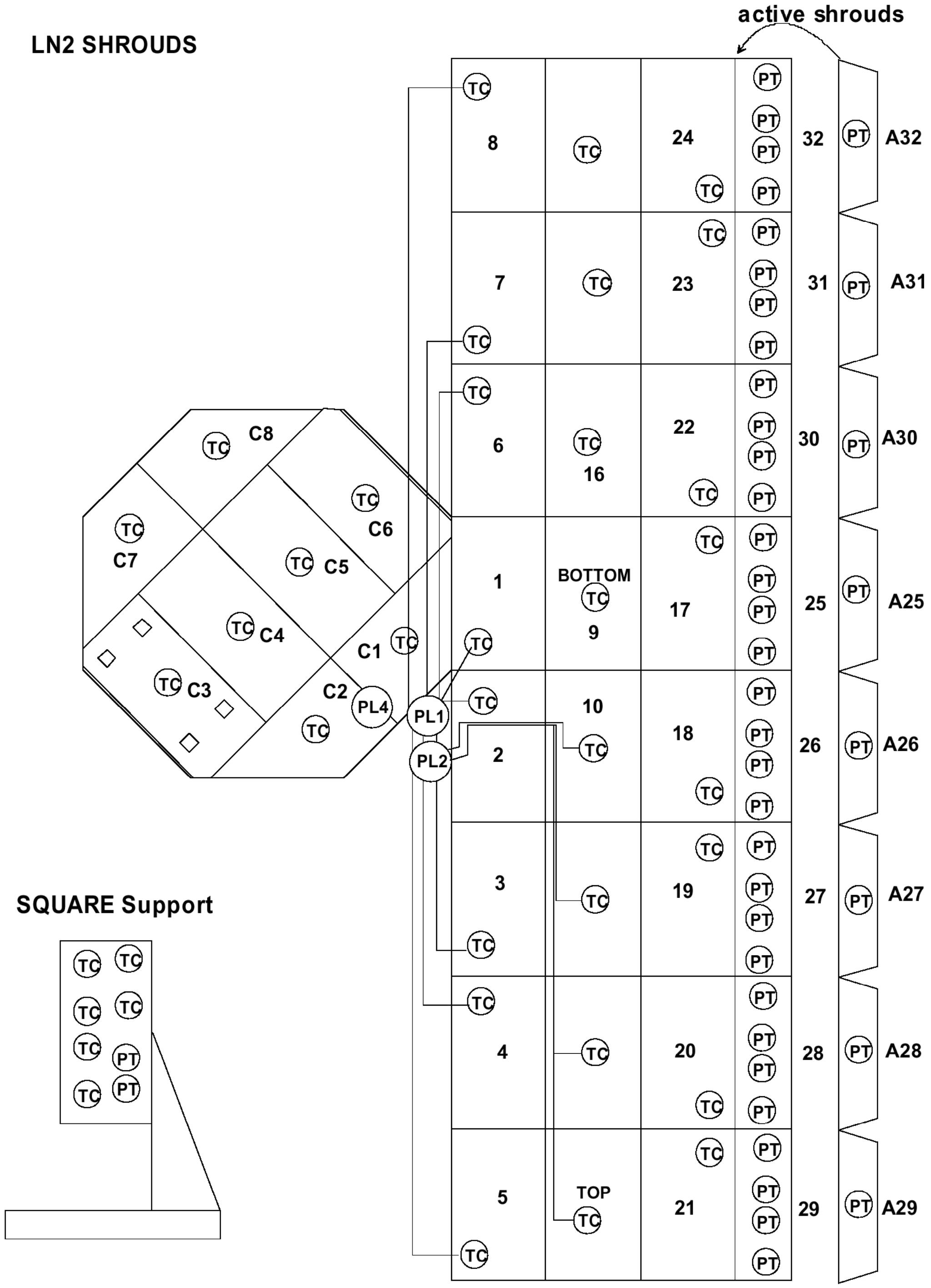


Figure 4-8: Thermal sensor localisation on Liquid Nitrogen shrouds.

5. TEST DEFINITION

5.1 Chronology

The following sections give the overall chronology of the test.

5.1.1 Phase 0.0 (Final check before chamber closure)

Ph0.0-001	Title Facility Check	Duration -
	Start Criteria -	End Criteria Activities completed
	Activity Final connections and associated checks.	

Ph0.0-002	Title S/C Short Functional check	Duration -
	Start Criteria After Ph0.0-001	End Criteria Activities completed
	Activity Avionic test SCS Healthcheck	

Ph0.0-003	Title Final check before pumping	Duration -
	Start Criteria - After Ph0.0-002	End Criteria Activities completed
	Activity 1/ Facility Activity – Check that all air inlet are closed 2/ Facility Activity – Check that all facility electrical powers are stopped inside the vacuum. 3/ AAS-F Activity - Check that all S/C electrical powers are stopped during pumping 4/ Closing of the chamber door	

The duration of this phase is estimated at 3 days.

5.1.2 Phase 0.1 (PUMP DOWN)

Ph0.1-001	Title Pumping phase up-to 5 10^{-5}mb	Duration 3 days
	Start Criteria End Of Phase 0.0-003	End Criteria <5 10^{-5}mb
	Activity Switch-on the facility procedure to go down to <5 10^{-5}mb with associated leak check.	

Ph0.1-002	Title Facility Leak under vacuum		Duration -
	Start Criteria P < 1. 10^{-4} mbar	End Criteria End of Phase 0.1	
	Activity LN2 shrouds, He shrouds leak checks		

Ph0.1-003	Title De-sorption of CFRP		Duration 2 days
	Start Criteria End of Phase 0.1-001	End Criteria 2 days (TBC)	
	Activity: De-sorption of the CFRP under vacuum at ambient temperature		

5.1.3 Phase 0.2 (SHROUDS cooling)

Ph0.2-001	Title Cold shrouds filling		Duration: 1.5 days
	Start Criteria end of Phase 0.1	End Criteria He shrouds < 20K	
	Activity Shrouds filling with Nitrogen and Helium. Perform a facility leak check when the shrouds are at operational temperature		

5.1.4 Phase 1: COLD THERMAL BALANCE

Starting in parallel to phase 0.2

Ph1-001	Title Switch ON specimen		Duration -
	Start Criteria End of Phase 0.1	End Criteria Specimen units are ON	
	Activity Switch ON avionics (CDMU, PCDU, ACC). CDMU will start SVM thermal control Switch ON CRS's Switch ON TTC avionics (EPC, TWTA) Switch ON XPND1 MTD Tx line Switch ON 20N thrusters cat bed heaters Switch ON LVA ring test heaters to minimum flight level (see AD12) Switch ON solar array test heaters to minimum flight level (see AD12) Switch ON heat pipe heaters (see specific sequence described in chapter 5.3) Note: switch ON sequence to be determined to maintain SVM flight equipment above startup temperature during shrouds cool-down		

It is demonstrated on Planck that one TTC channel can remain switched ON for long periods in steady state condition without reaching maximum temperature limits on TTC units (see system CDR RID MTP-102).

Ph1-002	Title SVM COLD THERMAL BALANCE		Duration: 1.5 days
	Start Criteria End of Phase 1-001	End Criteria SVM stabilisation	
	Activity Monitor 0 flux interface between SVM and THA Wait for SVM (see stabilisation criteria in AD12) and groove 1 stabilisation (0.2 K/hour)		

5.1.5 Phase 2: SORPTION COOLER TEST PHASE

Based on PPLM cool down prediction (see section 5.4) the duration for the cold end cool down to 18 K is 5 days from SCS switch ON. So a more optimised sequence is to switch ON first the SCS and then the other equipments. So the Ph2-001 has been removed and integrated inside the Ph2-002.

Ph2-002	Title COLD SCC THERMAL BALANCE		Duration: 5 days
	Start Criteria End of Ph2-001 and T_{LVHX2} < 100 K	End Criteria stabilisation	
	Activity Switch ON SCS (see RD11) Switch ON STR 1 Switch ON all MTD's (see table 5-3) Switch ON SREM Switch ON 1N thrusters cat bed heaters Switch OFF 20N thrusters cat bed heaters (only minimum heating shall remain ON) Monitor the O flux interface between SVM and THA Wait for stabilisation : temperature of LVHX2 lower than 22.5 K and asymptotic, for SVM see AD12 Perform test to estimate SSC-R cooling power (see procedure in Annex 5)		

The Phase 2-003 TTC thermal balance has been deleted, as it appears that the EPC cannot stay in pre-heating mode for more than 3 minutes (except one time, during launch where it can stay in pre-heating mode during 3 hours). So the TTC chain is already switched ON during Ph1-001.

Ph2-004	Title STR thermal balance		Duration: 1 day
	Start Criteria end of Ph2-003	End Criteria stabilisation	
	Activity Switch ON STR2 (two STR are ON during that phase) Wait for stabilisation (see stabilisation criteria in AD12)		

Ph2-005	Title Nominal SCC thermal balance		Duration: 1 day
	Start Criteria end of Ph2-004	End Criteria stabilisation	
	Activity Increase LVA ring temperature to maximum flight level (see AD12) Increase solar array temperature to maximum flight level (see AD12) Monitor O flux interface between SVM and THA Wait for stabilisation: temperature of LVHX2 lower than 22.5 K and asymptotic, for SVM see AD12 Perform test to estimate SSC-R cooling power (see procedure in Annex 5)		

Ph2-006	Title Hot SCC thermal balance		Duration: 1 day
	Start Criteria end of Ph2-005	End Criteria stabilisation	
	Activity Modify SCC heating profile to increase the dissipation to maximum value (see RD11) Monitor O flux interface between SVM and THA Wait for stabilisation: temperature of LVHX2 lower than 22.5 K and asymptotic, for SVM see AD12 Perform check of Defrost mode Perform test to estimate SSC-R cooling power (see procedure in Annex 5)		

Ph2-007	Title SCC regeneration test (TBC)		Duration: 1 day
	Start Criteria end of Ph2-006	End Criteria Regeneration sequence completed	
	Activity Functionally test the regeneration sequence of the 6 SCC beds with a bed temperature limited to 475K (TBC). Steady state regulation time for each bed is 20 minutes (TBC). Check proper functioning of SCC after regeneration test (see RD11)		

5.1.6 Phase 3: SPECIMEN WARM UP

Ph3-001	Title Shrouds warm-up		Duration
	Start end of Ph2-006	End Criteria shrouds at ambient temperature	
	Activity Reduction of liquid flow in shrouds		

Ph3-002	Title Specimen switch OFF		Duration
	Start end of Ph2-006	End Criteria all units OFF	
	Activity Switch OFF SCS (see RD11) Switch OFF heat pipe heaters (see specific sequence described in chapter 5.3) Switch OFF MTD's Switch OFF avionics Switch OFF LVA ring test heaters Switch OFF solar array test heaters Switch OFF TRA heaters		

5.1.7 PHASE 4 (PRESSURE RECOVERY)

Start Phase: end of phase 3

Ph4-001	Title Pressure recovery		Duration 10 hrs
	Start Criteria S/C at ambient temperature	End Criteria Atmosphere pressure	
	Activity Pressure recovery with GN2 until 300mb with a slope of 2mb/min Perform an stabilisation at 300 mbar during 2hrs for specimen temperature check Pressure recovery with GN2 until 1000 mbar with a slope of 5mb/min		

5.2 Phase transition logic

The phases defined in the previous section describe all the activities to be performed during PFM#1 test. However, as all these activities are not sequential, the logic between phases is explained in the following diagram.

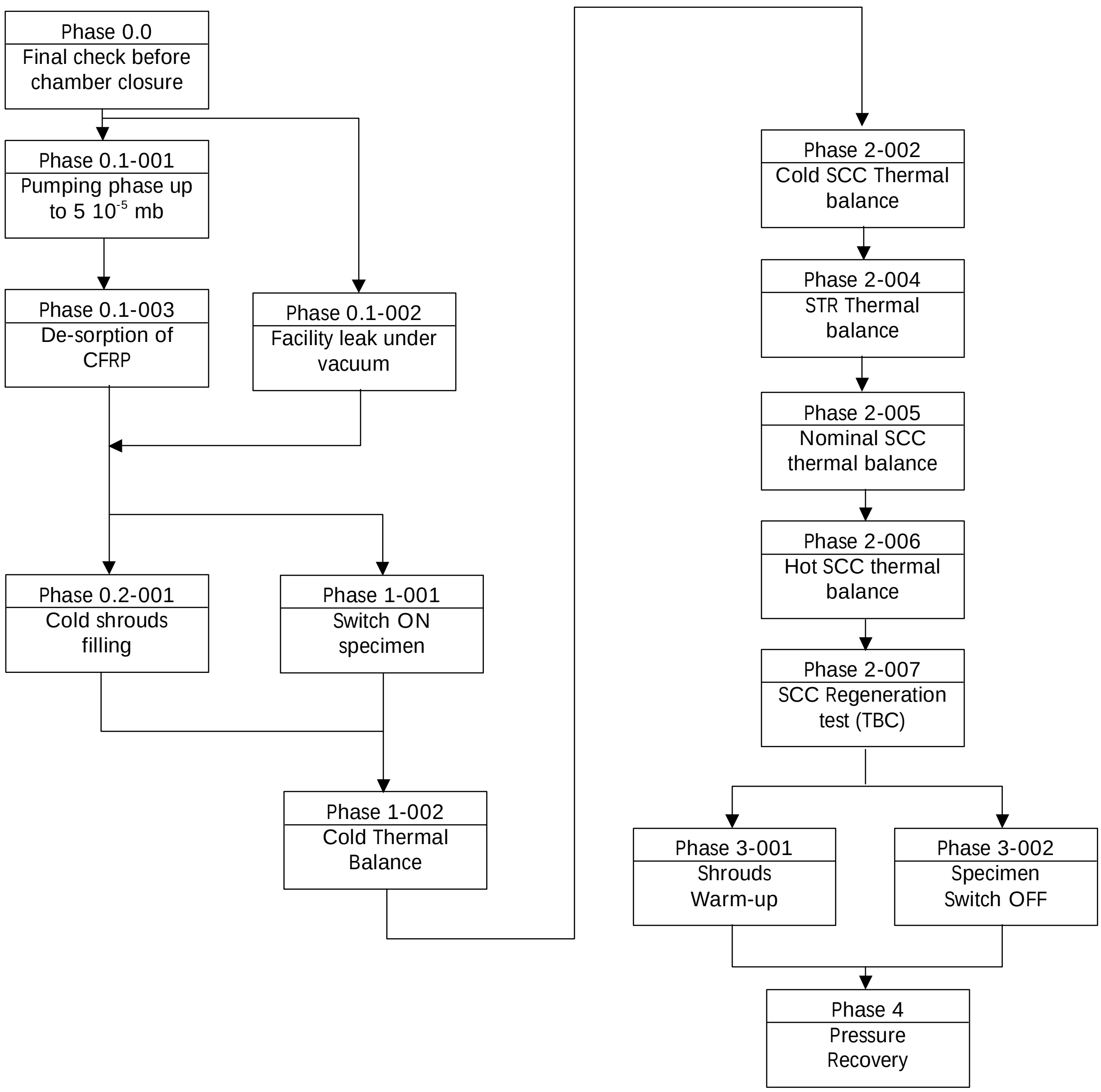
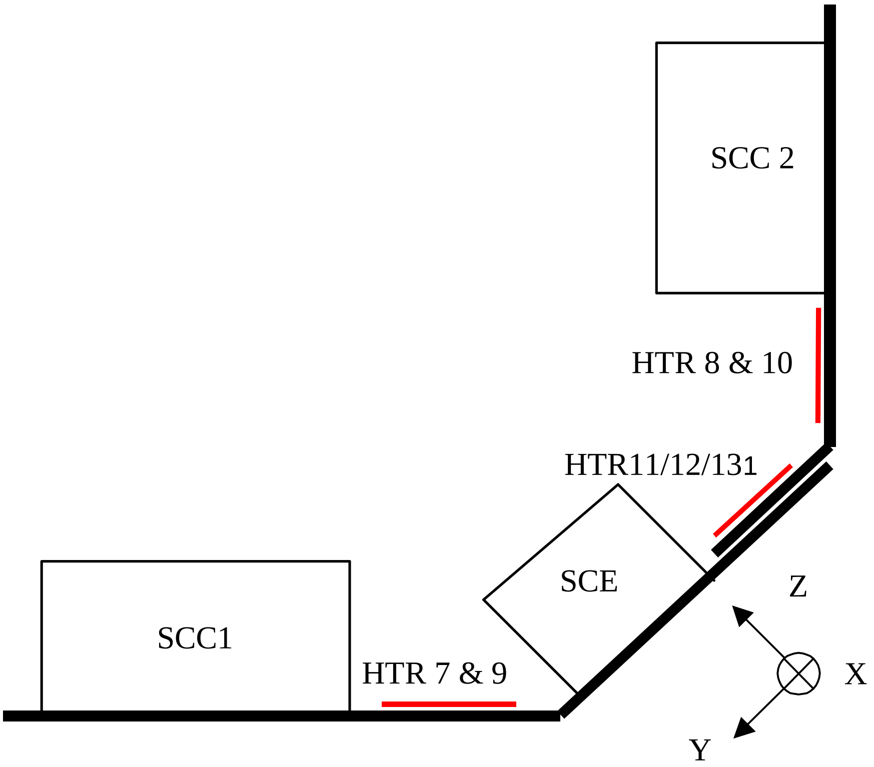


Figure 5-1: phase transition logic

5.3 Heat pipe heaters switching sequence

Configuration PFM#1: SCC 1 (R) On



Switching sequence

1- SCC/SCE Off: Ph01-001 (launch mode)

In flight the sequence of switching is: line 7 is activated first, line 13 is activated last.

On ground, in order to make sure there is no problem to operate the heat pipes it is preferable to force the following sequence:

- lines 7 & 9
- lines 11/12/13
- lines 8 & 10

As a consequence, the thresholds set up will be different to flight ones (see AD12).

The total power on the panels is 611W.

2- SCE ON: Ph02-002

In order to guaranty correct behaviour of the heat pipe, it is preferable to switch off the heating lines in the following sequence:

- lines 8 & 10
- line 12
- line 11
- line 13
- lines 7 & 9

This sequence gives the following decrease in power for the heat pipe network located under SCE1 and for the global heat pipe network.

Line turned OFF	number of heaters on SCE1 network	total number of heater	elementary decrease in power per line under SCE1	elementary decrease in power per line for total network	Total decrease in power for the network under SCE1	Total decrease in power for the total network	Power on SCE1 network	Power on total network
None	NA	NA	0	0	0	0	234	611
line 10	2	5	36.4	91	36.4	91	197.6	520
line 8	1	3	26	78	62.4	169	171.6	442
line 12	3	5	54.6	91	117	260	117	351
line 11	2	5	36.4	91	153.4	351	80.6	260
line 13	1	5	18.2	91	171.6	442	62.4	169
line 7	1	3	26	78	197.6	520	36.4	91
line 9	9	5	36.4	91	234	611	0	0

Due to the increase of temperature linked to the additional 110W dissipation of SCE1, line 10 may turn OFF and line 8 cycle (see test predictions in AD12). Lines 12/11/13 shall remain ON.

If one of the lines 11/12/13 is to turn OFF, it is preferable to turn OFF the lines having the biggest power installed on SCE1 network first in order to compensate the SCE1 dissipation. The sequence is hence 12/11/13.

See AD12 for details.

3- SCC 1 ON: Ph02-002

No specific constraint is identified before switching ON the SCC 1 (except panel temperature greater than minimum start up specified @-20°C and T_{LVHX2} < 175 K), after the SCC is turned on the heating lines 8 and 10 should naturally switch OFF because of the temperature increase.

See AD12 for details

4- Switching OFF: Ph03-002

The three previous steps are performed in the reverse order.

See AD12 for details.

Conclusions:

- no need for specific start up heaters
- need for a specific thermal analysis to simulate the switching sequence and check the compliance to temperature requirements.
- no specific manual operation is foreseen to follow the switching sequence of SCE1/SCC1. Only a modification of line thresholds is needed.
- the line shall be turned ON according to the sequence 7/9/13/11/12/8/10. The thresholds shall be implemented accordingly for test.

5.4 Preliminary thermal predictions

Phase description	Duration (days)	Duration issued from simulation	Comments
Pump down (from Ph0.1-001 to Ph0.1-003)	5	NO	Same as CQM
Shrouds cooling (Ph0.2-001)	1.5	YES	PPLM test prediction (AD11)
Cold thermal balance – launch mode (from Ph01-001 to Ph01-002)	1.5	NO	Estimate
Cold SCC Thermal balance (Ph02-002)	5	YES	PPLM test prediction (AD11)
STR Thermal balance (Ph02-004)	1	NO	Estimate
Nominal SCC thermal balance (Ph02-005)	1	NO	Estimate
Hot SCC thermal balance (Ph02-006)	1	NO	Estimate
SCC Regeneration (Ph02-007)	1	NO	Estimate
Warm-up (from Ph03-001 to Ph03-002)	4	YES	PPLM test prediction (AD11)
Pressure recovery (Ph04-001)	1	NO	Same as CQM
Total	22		

Table 5-1: Vacuum phase's duration synthesis

The durations for the phases are illustrated in Figures 5-2 and 5-3 which shows the temperature of various specimen elements during the cool-down phase (Figure 5-2) and the warm-up phase (Figure 5-3). These plots are extracted from document AD11 which gives all the details and hypothesis for these simulations.

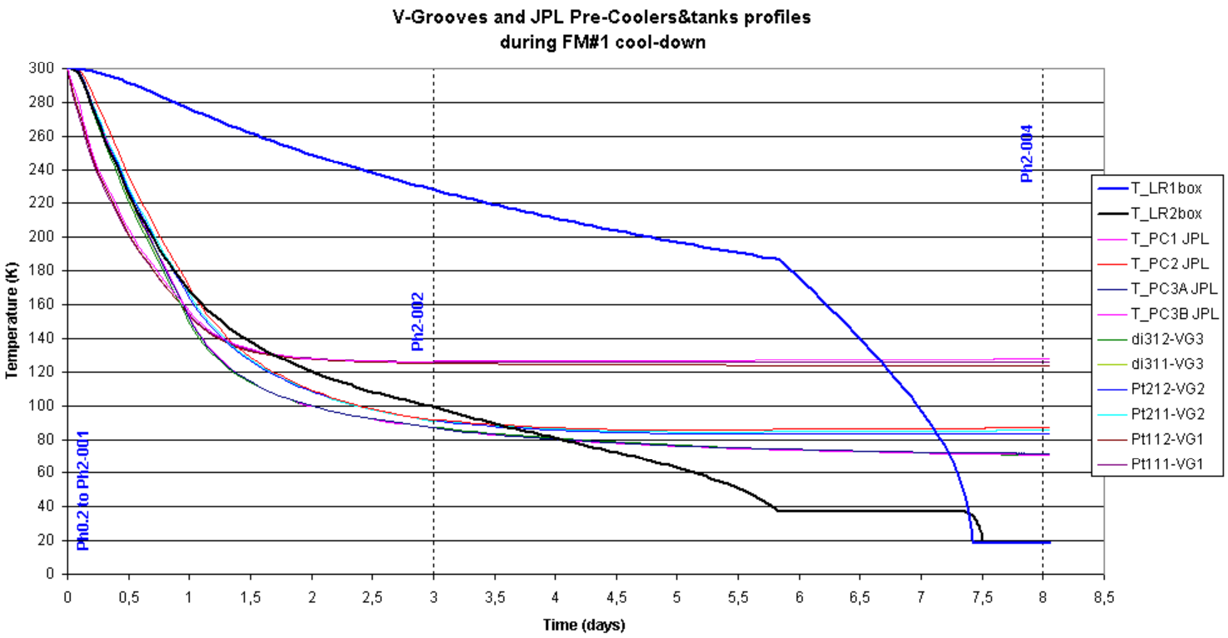


Figure 5-2: Thermal simulation for Phase 0.2 to beginning of Phase 2-004

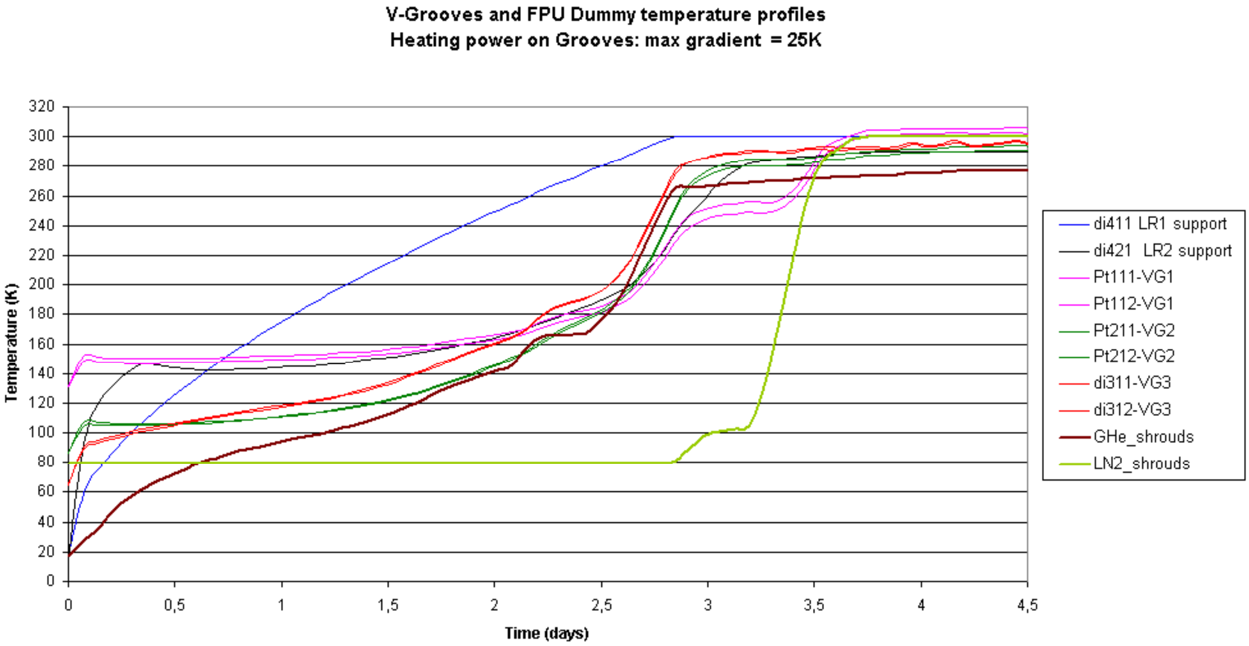


Figure 5-3: Thermal simulation for Phase 3

The following table shows the activities to be performed for SVM thermal test prediction (by AAS-I)

Phase	Phase description	Objective
Phase 1-001	Switch ON specimen	Switch ON sequence to maintain SVM equipments inside requirements, including heat pipe heater switching sequence/thresholds Definition of LVA ring + Solar array heating power
Phase 1-002	SVM cold thermal balance	SVM temperature prediction + SVM stabilisation criteria Definition of LVA ring + Solar array heating power
Phase 2-002	Cold SCC thermal balance	SVM temperature prediction + SVM stabilisation criteria Heat pipe heater switching sequence/thresholds Definition of LVA ring + Solar array heating power
Phase 2-004	STR thermal balance	SVM temperature prediction + SVM stabilisation criteria
Phase 2-005	Nominal SCC thermal balance	SVM temperature prediction + SVM stabilisation criteria Definition of LVA ring + Solar array heating power
Phase 2-006	Hot SCC thermal balance	SVM temperature prediction + SVM stabilisation criteria Heat pipe heater switching sequence/thresholds Definition of LVA ring + Solar array heating power

Phase 2-007	SCC regeneration test (TBC)	SVM temperature prediction + SVM stabilisation criteria Heat pipe heater switching sequence/thresholds
Phase 3-002	Specimen switch OFF	Switch OFF sequence to maintain SVM equipments inside requirements, including heat pipe heater switching sequence/thresholds Definition of LVA ring + Solar array heating power

In the previous table, the SVM designates the full Service Module, including platform equipments, MTD's and SCS.

The following table shows the activities to be performed for PPLM thermal test prediction (by AAS-F)

Phase	Phase description	Objective
Phase 0.2	Shrouds cooling	PPLM passive cooling profile/duration
Phase 1-002	SVM cold thermal balance	PPLM temperature prediction + Groove 1 stabilisation criteria
Phase 3	Specimen warm-up	PPLM temperature profile/phase duration

5.5 Test sequence configurations

This chapter presents the test configurations all along the test sequence and transitions between these configurations.

5.5.1 SVM configurations

5.5.1.1 Configuration overview

5.5.1.1.1 Power

The satellite power SHALL be supplied and controlled through its umbilical interface.

The power supply SHALL be provided by the SAS.

The flight battery will be present on the SVM for the test, but it SHALL remain unconnected. A protective cap SHALL be set on the battery safety skin plug socket, but the connection SHALL remain open. The use of the BATSIM is not considered for the test.

For turn ON, the SAS power shall be raised progressively by turning ON the sections one by one and/or ramping the SAS delivered current slowly from 0 A to nominal maximum (2.2 A per section). No single operation error shall allow turning ON the sections supply all at once at full power: the core need is that the power bus capacitor initial charging current shall not exceed 71A.

The baseline is that the possible power peak demand associated with a worst case heater duty cycle combination SHALL be handled by allowing a few more power from SAS than flight nominal (S3R capacity is higher than strict solar array capability).

5.5.1.1.2 Commandability and observability

The satellite SHALL be commanded and monitored through its umbilical interface.

Additional link SHALL be provided -not accounting for the specific thermal test harness- to:

- spy the CDMS 1553 busses from the dedicated skin plug,
- enable switching ON of the TWTA1. For this purpose, the LGA1 will be removed and replaced by a wave guide to coaxial transition connected to a RF load.
- The MGA will be removed and replaced by a wave guide to coaxial transition connected to a RF load to allow switching ON of the redundant chain or TWTA2 alone.

To ensure against a configuration mistake leading to radiate an uncontrolled RF power in the test facility, the RFDN SHALL be configured before the test such that:

- TWTA1 is connected to LGA1
- TWTA2 is connected to MGA

The corresponding RFDN configuration is:

- SW1, SW2 in position “B”
- SW3 in position “A”
- SW4 in position “B”

In order to avoid any command mistake leading to RF radiation through LGA2 and LGA3, the switch commands to unwanted positions shall be defined as dangerous commands in the TM/TC DFE. This means that it shall be impossible to command SW1 and SW2 in position “A”, SW3 in position “B” and SW4 in position “A”.

- The thruster firing safety plug SHALL be used to prevent a spurious 20N or 1N command valve activation. No valve load simulation by the EGSE is necessary, and command line MAY be left open.

For the test sequence, the TCS (thermal control) function activity is vital to satellite unit survival and this service operation continuity SHALL be ensured in a fail safe way.

5.5.1.1.3 Operation mode

The baseline for operation SHALL be to operate the satellite in “launch” mode (considering CDMS and ACMS software mode).

All the separation straps SHALL remain closed (launch configuration) for the whole test duration.

The test baseline is to operate the satellite from the most basic “launch” mode obtained from power-up reset (power-up reset is recognised by the ACC and CDMU software).

In case of contingency, the baseline for the CDMU SHALL be to:

- first try a PM-A reset (PM-A is default turn ON configuration),
- if not successful, try a switchover on PM-B.

Considering a trouble with RM usage at present SVM validation state, both CDMU and ACC RM will be disabled. Then the CDMU will be unable to trig any autonomous reconfiguration. PM-A reset or switch-over to PM-B shall be directly commanded from the CCS by direct CPDU command (TC(2,1) on MAP0) on the respective PM reset or PM ON/OFF relays.

As the test will be associated with the satellite continuous operation for two weeks typically, a specifically feared even will be with software long term endurance. A need to periodically reset the satellite and reload the test configuration SHALL be taken into account among possible contingency cases (software stall), to be detailed in emergency procedure.

In case of occurrence, the test configuration shall be fully reloaded. Such a switch over or reset will be associated with a complex initialisation by the application software from CDMU PM EPROM. To ensure a proper reconfiguration (reset of power ON flag in the RM registers) a turn OFF / ON form the SAS may be considered to force a “clean” configuration on PM-A. Else, as a minimum precaution, the RM register will be reset by sending a TC packet (content does not care) on VC0/MAP5 and VC1/MAP5 (this trig a reset of the RM core ASIC).

As a RM disabling consequence, the software watch dog will not be operational. A CCS routine will have to provide an equivalent function during the test long waiting periods. Baseline is the monitoring by the CCS of a suitable dynamic TM parameters (e.g. counters) to determine whether the CDMS SW is stalled or not. In case of anomaly, the PM shall be rested and configuration reloaded.

5.5.1.1.4 Operation limitation and constraint from software release

The satellite will be run with V1 software for both the ACC and CDMU ASW. This is associated with the main following limitations:

- the FDIR services (recovery action on alarm event) are not available,
- the CDMS OBCP (on board command procedure) service is not available,
- the CDMS MTL (mission time line) service is not available,

The satellite SHALL be operated on a full real time basis from the CCS.

For the CDMU, the missing FDIR and MOT service imply that –in most cases of anomaly- no event packet will be generated. Only the BSW managed cases will involve an on board processing. Outside those cases (mainly 1553 bus FDIR), the CDMU will undertake no corrective action

For the alarm cases which may be relevant to the PFM1 test security, the CCS SHALL monitor the critical HK TM packets and recognise the event packets, to handle the proper recovery actions (this will be analysed case by case).

In addition to service limitation, the hypothesis is that the V1 software release will include default setting (data base entry) for parameters which will be obsolete or limited with respect to test configuration and needs. The satellite configuration for PFM1 test SHALL foresee at least to load:

- the TCT (thermal control table) update

As fuel tanks are not installed, the corresponding TCS loops shall remain disabled.

The TCS operation nominally use for some thermal control line, the “unit in use table” entries to switch between “operating” and “non operating” regulation parameter sets. But the unit in use table is managed nominally by the FDIR service, which is not available with V1 software. To cope with a complex MTD heritage, some LCL lines are not used with PFM1 test for their flight purpose. The instrument control units –replaced by MTD- will not either report by an event packet the ON/OFF switching of unit normally under their secondary power supply. As a global result, the PMF1 test SHALL not rely on the “unit in use table”.

As a work around, the TCT table SHALL be reloaded (as necessary) for each balance case, with the “operating” and “non operating” parameters both set on the wanted value for the test phase (specifically for MTD). In this way, the TCS settings will be correct whatever the state of the “unit in use table” is.

5.5.1.1.5 SCS Operation Safety concern

The SCS includes an autonomous FDIR algorithm. In case an anomaly occurs that it cannot handle, the SCE sends a specific event packet:

- TM(5,4) to which CDMS should nominally react by turning OFF the SCE.

As the CDMS FDIR service (EAT) is not available for PFM1 test, the equivalent functionality shall be implemented in the CCS.

In case this event is observed, the following SCE emergency switch OFF sequence shall be run:

emergency SCE shut down	turn OFF the SCE-R power input from a PCDU management service unit OFF command. if the SCE is sinking power when the first LCL's are turn OFF, this may cause the remaining ones to trip OFF automatically. The OFF command shall be send whatever.	TC(8,4,112,3h) LCL 63d, 64d,65d, 66d
	the S/C HK telemetry shall confirm the 4 SCE-R power input shut down (status and current)	
	turn OFF then the SCE-R from a PCDU management service unit OFF command.	TC(8,4,112,3h) LCL 53d
TCT table update	load the Phase 1 TCT and check it. (This is only necessary if Heat Pipes heaters thresholds in Phase 2 TCT are different from those of Phase 1 TCT)	TC(8,4,114,18) to load TC(8,5,114) to read back

5.5.1.1.6 SCS Observability concerns

To ensure the SCE observability during the test, the telecommand packets shall be send toward the SCE with the acknowledgement flags set in the packet header. This means that each command packet shall be echoed by TC verification service packets:

- TM(1,1): TC acceptance success, or
- TM(1,3): TC execution start success, and TM(1,7): TC execution completion success.

The settings defined in the HPSDB shall be used (acceptance only, except for service 6 related commands). More flags shall not be requested (risk of 1553 bus protocol saturation).

The SCE does not support any command packet that support TC execution sub step execution, then no TM(1,5) shall be recorded nor even asked for (4th TC acknowledge flag).

5.5.1.1.7 CDMS V1 software compatibility concerns with SCS operations

The SCE turn ON and turn OFF nominal procedures include an handshake with the CDMS for the purpose of synchronising the SCE power input line switching ON and OFF by the PCDU, with the internal SCE state transition. This handshake uses nominally CDMS action on SCE emitted event packets:

0 TM(5,1) ID 3: CDMS shall turn ON the SCE power input (LCL 63d, 64d, 65d, 66d turn ON by a PCDU command service TC(8,4,112,5h).

1 TM(5,1) ID 9: CDMS shall turn OFF the SCE power input (LCL 63d, 64d, 65d, 66d turn OFF by a PCDU command service TC(8,4,112,5h).

As the EAT is not implemented in PMF1 available CDMS software, then the CDMS will not react to those event packets. The functionality shall be implemented at CCS level.

Note: as the CDMS MOT and UIU tables associated services are not operational with PFM1 CDMS software, and then no update attempt shall be made when turning ON and OFF the SCE and SCC (this would generate useless error event packets).

5.5.1.2 Switching status during PFM#1

The Table 5-3 shows the switching status (ON/OFF) of the SVM units during the PFM#1 test phases.

	Phase 0.1	Phase 0.2(1)	Phase 1	Phase 2-002	Phase 2-004	Phase 2-005	Phase 2-006	Phase 2-007	Phase 3-001	Phase 3-002	Mini-IST
CDMU	OFF	N/A	ON	ON	ON	ON	ON	ON	ON	OFF	ON
ACC	OFF	N/A	ON	ON	ON	ON	ON	ON	ON	OFF	ON
STR1	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
STR2	OFF	N/A	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	Transient
CRS1	OFF	N/A	ON	ON	ON	ON	ON	ON	ON	OFF	ON
CRS2	OFF	N/A	ON	ON	ON	ON	ON	ON	ON	OFF	ON
CRS3	OFF	N/A	ON	ON	ON	ON	ON	ON	ON	OFF	ON
EPC1	OFF	N/A	ON	ON	ON	ON	ON	ON	ON	OFF	ON
EPC 2	OFF	N/A	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
TWT1	OFF	N/A	ON	ON	ON	ON	ON	ON	ON	OFF	ON
TWT2	OFF	N/A	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
PCDU	OFF	N/A	ON	ON	ON	ON	ON	ON	ON	OFF	ON
PT	OFF	N/A	ON	ON	ON	ON	ON	ON	ON	OFF	ON
SREM	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
SCE-R	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
SCC-R	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
SCE-N	OFF	N/A	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
SCC-N	OFF	N/A	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
1N-Thrusters cat bed heating	OFF	N/A	OFF	ON	ON	ON	ON	ON	OFF	OFF	Transient
20N-Thrusters minimum heating	OFF	N/A	ON	ON	ON	ON	ON	ON	ON	OFF	ON
20N-Thrusters cat bed heating	OFF	N/A	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	Transient
Latch valve	OFF	N/A	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
MTD's		N/A									
XPND1	OFF	N/A	ON	ON	ON	ON	ON	ON	ON	OFF	ON

XPND2	OFF	N/A	Rx	Rx	Rx	Rx	Rx	Rx	Rx	OFF	Rx
FOG GEU	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
BEU	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
DAE	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
REBA-N	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
REBA-R	OFF	N/A	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
DPU-N	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
DPU-R	OFF	N/A	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
PAU	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
REU	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
4K-CCU	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
4K-CAU	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
4K-CDE	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
4K-CCR	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient
DCCU	OFF	N/A	OFF	ON	ON	ON	ON	ON	ON	OFF	Transient

(1) During Phase 0.2, the SVM equipments will be switched ON in sequence according to thermal needs resulting in the switching status of Phase 1

Table 5-2: Switching status for SVM units during PFM#1 test

5.5.1.3 Skin connectors configuration

SK01B	J01	Battery-PCDU Power	Not connected
	J02	Battery-PCDU Power	Not connected
	J11	BDR1 ON/OFF Command	Not used
	J12	BDR2 ON/OFF Command	Not used
SK02	J01	1553 Bus A	Connected to CDMS SCOE
	J02	1553 Bus B	Connected to CDMS SCOE
	J03	1553 Bus A	Not connected
	J04	1553 Bus B	Not connected
	J05	Thruster commands	Not connected
	J06	Thruster commands	Not connected
	J07	Pressure transducer & Tank thermistors	Connected (tank thermistors not present)
	J08	LV status and Thruster thermocouples	Connected
	J09	Quick load	Not used
	J10	Quick load	Not used
	J11	LV status and Thruster thermocouples	Connected
	J12	Thruster heaters	Connected
	J13	Thruster heaters	Connected
	J14	STR1 commands & status	Connected
	J15	STR2 commands & status	Connected
SK05	J01	CRS1 Outputs	Connected
	J02	CRS2 Outputs	Connected
	J03	CRS3 Outputs	Connected
	J05	AAD Outputs	Connected
	J06	SAS1 & 2 Outputs	Connected
	J07	SAS1 & 2 Outputs	Connected
	J08	AAD Outputs	Connected
	J04	CRS Stimuli	Not used
SK03	J01	Aux TC Inputs	Not used (also present on umbilical)
	J02	Aux TC Inputs	Not used (also present on umbilical)
SK06	J01	STR1 stimuli	Not used
	J02	STR2 Stimuli	Not used

5.5.1.4 Operation during test phases

5.5.1.4.1 Phase 0.0 Final check before chamber closure, PHASE 0.0-002 S/C Short functional check

The purpose of this test is to check that the full test sequence can be run without fault in the exact test configuration and EGSE environment (including chamber wall feed through connectors).

The test baseline is to run the full test sequence in an accelerated way. The SCS activation sequence will be nevertheless specifically adapted to cope with SCS ambient condition activation constrains.

The rationale for a full accelerated test, with respect to a simpler health check sequence is that, if this sequence will have been repeated in Cannes premises, satellite environment and EGSE to satellite harness will be partly new, and a loss of satellite control during test can be specifically critical.

With respect to the nominal test sequence, the sequence compaction implies specifically that

- no thermal equilibrium will be waited for.

With respect to the test repetition in Cannes, the test sequence will be run without ambient condition cooling assistance (fans). This will imply that the sequence shortened time will include maximum activation time out, and minimum relaxation time between activations. This specifically concerns:

- PCDU at full charge,
- TWTA1

Baseline, in case of major anomaly during this functional check, is to turn the satellite OFF. This considers a difference with respect to the nominal test sequence for which TCS function activity will be vital to satellite survival and satellite operation continuity will have to be enforced in a fail safe way.

5.5.1.4.2 Phase 0.1 Pump down

The satellite SHALL be OFF and SHALL be maintained OFF for the pump down phase.

The rationale is that while shrouds remains at ambient temperature, the satellite radiator cannot evacuate the power dissipation without units reaching an excessive temperature.

Any erroneous satellite activation SHALL be limited to a time compatible with the satellite thermal inertia on most sensitive elements. Erroneous satellite activation shall be avoided by procedure.

5.5.1.4.3 Phase 1-001 Switch-on specimen

The switch ON of the specimen will in fact occur in parallel to the shrouds cooling to avoid too low temperature on the specimen.

The satellite SHALL be turned ON, its operation checked with an updated parameter set, specifically TCS table.

The shroud cooling can lead to a too low temperature on some satellite units if TCS is not activated to keep them at a safe temperature (SCC is the identified critical point). In turn, non cooled shroud forbid satellite activation, then TCS activation. The satellite activation SHALL be so synchronised with the shroud cooling based on a min. / max. time delay with respect to cooling start-up or on shroud temperature readings.

The detailed satellite control sequence SHALL be the following:

Note1: the 3rd column gives links to standard command codes. This is given for information only at this step of test preparation, and because their knowledge allow for quick “search” through software documentation. For most sequence step, the command and the associated TM check are to be validated at sub-system SIT level first. The SIT entry and procedure will paste the 3rd column entries when available.

synchronisation with shroud cooling	turn ON and verify EGSE	
	when Ok give GO ahead for shroud cooling start-up	
	wait shroud cooling criteria for satellite turns ON	
	turn ON the satellite according to RD12 (CDMU PM-A on SAS configuration)	
check boot	monitor correct CDMU boot and power ON type initialisation in "launch" mode.	TM(5,1,101,1) gives recognised initialisation condition
start CCS anomaly monitoring watch dog	engage the CCS HK and event message packets screening for a case needing a recovery actions (including OBSW stall detection).	
configure TM	check that TTC management service is ON (set it ON if not)	TC(8,1,115) to start if necessary
	enable all TM packet down-link	TC(14,5) APID 0 and type 0 (down-link all)
	suppress TM sub-sampling	TC(8,4,115,17d)
	verify event filtering service is OFF (all event packets are send to ground). Set it OFF if not.	TC(8,5,117) to verify TC(8,2,117) to stop
	confirm enable real time housekeeping TM packet generation	TC(14,1) on service 3
check EPS	check that the CRS and the EPC are OFF (they will be set ON if power-on condition has not been recognised). turn OFF the EPC if it is ON from the TTC service (hypothesis is that at shroud cooling beginning, dissipated power shall be limited)	happen only if a CDMU reset occurs TC(8,4,115,2d) on unit 1 (TX) and 4 (EPC)
	check that PCDU HPS are all ON (no trouble with any heater line). After 6 minutes, the redundant HPS shall be turned OFF autonomously (delayed activation of the TCS service).	status part of essential HK.
	check that all unit LCL (11d to 70d) are OFF except the "cold" lines of CDMU (31, 32)	status part of essential HK
configure TCS	load the Phase 1 TCT (see Annex 4) and check it.	TC(8,4,114,18) to load TC(8,5,114) to read back
	enable all TCS control loops (except tanks)	TC(8,5,114,1)

turn ON the 20N Cat Bed min. HTR	turn ON the 20N Cat Bed minimum heaters from the PCDU management service	TC(8,4,112,5h) for LCL 17d 18d
in case of a failure during the configuration	For the initial configuration, the number of configuration retry if any is 1 on the same PM-A (in case of autonomous switch-over, or similar anomaly, the reset will be done after confirming all the CDMU configuration relays (RM disable, PM active = A, software image 1).	
GO / NO GO to shroud cooling operation ending	check that the TCS service is actually active	
	give GO / NO GO for ending shroud cooling operation (if the TCS correct operation is not successful, the cooling operation shall be aborted)	

Note: on board time in not set. The hypothesis is that default initialisation time is get from first HK packets and the test event chronology can be correlated from this (as no packet store is used, all packets are real time).

Synchronisation with shroud cooling	wait the shroud cooling condition which can match the full avionics panel dissipated power.	
turn ON the SSMM	activate the mass memory controller. All banks shall remain OFF.	
	The formatting of the Mass Memory shall not be attempted. The SSMM is not functional with PFM1 OBSW configuration. The packet storage shall not be activated.	
Complete the test configuration	turn ON the 3 CRS from the PCDU management service.	TC(8,4,112,5h) for LCL 15d, 24d and 25d
	turn ON the TWT1 from the TTC management service check EPC is turned ON and the TWT activation after warm-up time (about 35+180s)	
Complement avionics and auxiliary configuration	turn ON the ACC cold-A and cold-B LCL from PCDU management service enable the ACC RM by direct TC	TC(8,4,122,5h) LCL 33d 34d TC(2,1) line 21 and 24
	monitor correct ACC boot and power ON type initialisation in “launch” mode (stand-by).	TM(5,1,101,1) gives recognised initialisation condition

	engage the ACC BSW software alarm event message and HK packet screening by SCC for a case needing a recovery actions.	
	turn ON the RCS Thruster (FCV and THR) branch A LCL form the PCDU management service	TC(8,4,122,5h) LCL 45d
	turn ON the 20N Cat Bed heaters of RCS-1 branch (confirm 1N HTR OFF)	TC(8,1,245) to set configuration inputs, then TC(8,4,245) to execute (critical command)

5.5.1.4.4 Phase 02- 002: sorption cooler test phase

Configure TCS	Update if necessary TCT for lines 7 to 13 and 61 to 67 (Heat pipes heaters) and check it. See values in Annex 4, TCT for Phase 2-002.	TC(8,4,114,18) to load TC(8,5,114) to read back
Start the SCS	switch bus profile to profile 2. Enable the pooling of SCE TM packets.	TC(8,4,6,4)
	Enable SCS HK TM packet downlink	TC(14,1)
	turn ON the Sorption Cooler Electronics SCE2 from the PCDU management service	TC(8,4,112,5h) LCL 53d
	follow the SCE start-up detail procedure described in the dedicated document. Specifically (recall): activate the CCS monitoring of any emergency stop requesting event packet TN(5,4) ID 11 turn ON the 4 SCE power input LCL (redundant channels) when SCE sent the synchronising event TM(5,1) ID1	see dedicated procedure in RD11 TC(8,4,112,5h) LCL 63d, 64d, 65d, 66d
	Verify loaded LUT is the correct one for TV / "low power" case test	see dedicated procedure
	Launch the SCE into RUN Mode (compressor operation)	see dedicated procedure in RD11

	check for correct sorption cooler start-up check for satellite power consumption check for correct heat pipe start-up from TM and test thermo-couple (heater line 10 and 8 turn OFF by themselves first) Command back the SCE in Shut Down in case of anomaly with heat pipe start-up	see dedicated procedure in RD11

While the SCS is cooling down (estimated about 5 days), the configuration shall be completed by the following settings.

Update the avionics and auxiliary configuration	turn ON the STR1 LCL from the PCDU management service turn ON the STR1 from the ACC service 8, TC_SWITCH_ACMS_UNITS_ONOFF function	TC(8,4,112,5h) LCL 21d TC(8,1,202,2) on unit 3,1 (STR1)
	command a CCD raw image dump to check STR health	see dedicated procedure
	turn OFF the 20N Cat Bed heaters of RCS-1 branch and turn the 1N ones ON	TC(8,1,245) to set configuration inputs, then TC(8,4,245) to execute (critical command)
	turn ON the FOG1 LCL from the PCDU management service All FOG nom MTD heaters are on FOG1 LCL. Red MTD heaters are on FOG2, and shall be left OFF (dislike flight) to respect nominal power dissipation, FOG 3 and 4 LCL are unused then shall be preferably left OFF)	TC(8,4,112,5h) LCL 13d (do not actuate LCL 14d, 26d, and 35d dislike flight)
	turn ON the SREM from the PCDU management service	TC(8,4,112,5h) LCL 19d
configure instrument unit MTD	turn ON the 4Kcooler MTD from the PCDU management service: on the 4K-CDE and 4K-PWR nom and red no1 LCL (this is not a flight possible configuration) the different 4K cooler MTD are spread on the CDE and PWR nom and red LCL so both shall be activated dislike in flight. In turn the second LCL of the 4K no2 PWR lines of nom and red channel are not used, then shall be better left OFF	TC(8,4,112,5h) LCL 37d then 59d,AND 61d (but not 60d and 62d)

	turn ON the LFI experiment MTD from the PCDU management service: on the nom REBA and nom and red DAE LCL. BEU and DAE MDT are spread on the DAE unit nom and red LCL. Then both nom and red DAE LCL (dislike flight) shall be activated for representative power dissipation.	TC(8,4,112,5h) LCL 27d, (not 28d) then 51d AND 52d
	turn ON the HFI experiment MTD from the PCDU management service: on the nom DPU, REU, DCE then the 2 first REU belt LCL nom REU MDT are all on 6&7 and 8&9 belt. The 0&1 and 2&3 LCL are reserve for red MTD heaters and the 2 last REU LCL are unused. So only 2 of the 6 lines shall be activated)	TC(8,4,112,5h) LCL 29d, 11d, 36d, then 42d, 43d (NOT 39d, 40d, 41d and 44d).
update the TCT table to new test phase	load the Phase 2-002 TCT (see Annex 4) and check it. (Note: the hypothesis is here that the avionics and instrument activation is done without specific waiting time between steps. If this is not the case, or if this may simplify the operation procedure, the TCT table can be updated line per line after each unit (or MTD) activation to emulate more closely the TCT parameter switching nominally automatically associated (NB. unit in use table is not operated for PFM1 test).	TC(8,4,114,18) to load TC(8,5,114) to read back

The above command scenario supposes that all MTD nominal heaters are operational. If one is failed, most MTD are fit with a redundant heater that is wired. If an MTD nominal heater degradation is observed during check out, the command sequence will have possibly to be modified to use rather the redundant heater. The above command scenario point out their allocation when available.

5.5.1.4.5 Phase 02-004: STR hot redundancy test

Phase 02-004 consider a switch ON of the two star trackers to check the thermal behaviour in this configuration.

STR2 turn ON	turn ON the STR2 LCL from the PCDU management service turn ON the STR2 from the ACC service 8, TC_SWITCH_ACMS_UNITS_ONOFF function	TC(8,4,112,5h) LCL 22d TC(8,1,202,2) on unit 3,2 (STR2)

update the TCT table to new test phase	load the Phase 2-004 TCT (see Annex 4) and check it. Note: only the thresholds (N and R) for STR2 thermal control are changed w.r.t. Phase 2-002 TCT. So, it is preferable to only update the 2 corresponding lines	TC(8,4,114,18) to load TC(8,5,114) to read back
STR2 health check	command a CCD raw image dump to check STR2 health	

STR2 return to OFF after test phase	turn OFF the STR2 from the ACC service 8, TC_SWITCH_ACMS_UNITS_ONOFF function turn OFF the STR2 LCL from the PCDU management service	TC(8,1,202,1) on unit 3,2 (STR2) TC(8,4,112,3h) LCL 22d
update the TCT table to new test phase	load the Phase 2-002 TCT (see Annex 4) and check it. Note: only the thresholds (N and R) for STR2 thermal control are changed w.r.t. Phase 2-004 TCT. So, it is preferable to only update the 2 corresponding lines	TC(8,4,114,18) to load TC(8,5,114) to read back

5.5.1.4.6 Phase 2-006: Sorption cooler power increase

Phase 2-006 consider a sorption cooler reconfiguration for maximum power dissipation.

set sorption cooler for higher power dissipation regime	send the TC packet (LUT loading) to SCE to configure the SCC for the wanted higher power dissipation test configuration	See dedicated procedure in RD11
	No update of TCT is necessary for this phase	

5.5.1.4.7 Phase 2-006 end: Defrost automatic sequence

End of phase 2-006 is used for a short test of the SCE JT and filter defrost sequence.

Note: the defrost heaters cannot support to be actuated in ambient condition. This sequence is so a passenger test on the PFM1 sequence which intends to check the correct end to end integration of those circuits.

force the sorption cooler into the defrost	Command the SCE into the defrost sequence	see dedicated procedure in RD11

automatic sequence	wait automatic sequence is completed (return to conditioning)	(1000s)
	wait SCE achieve again proper compressor state and automatically return to the "normal" operating state.	(about 2 to 3h)
Stop the compressor	Command back the SCE into ready mode / health monitoring	see dedicated procedure in RD11

5.5.1.4.8 Phase 2-007: Sorption cooler regeneration sequence test (TBC)

Phase 2-007 consider a test of the SCE embedded regeneration sequence.

Note: as the SCS will not be tested any more in a representative way before flight, the sequence is terminated with a last reference run of normal operation.

command a regeneration sequence	Verify the LUT entries for regeneration parameters	see dedicated procedure in RD11
	Command the SCE into regeneration mode	
	wait until the automated sequence is completed (the SCE shall return autonomously in Ready / Health monitoring)	
last SCS performance reference point	Verify the LUT entries for operation parameters ("high power" setting)	see dedicated procedures in RD11
	Command the SCE into RUN mode	
	wait SCE achieve again proper compressor state and automatically return to the "normal" operating state. Note: the setting are identical to the previous thermal balance one, so performance after/before regeneration shall be identical. Wait only 2 full cycles	
	No update of TCT is necessary for this phase	

5.5.1.4.9 Phase 03-001: Return to minimal configuration to manage shroud warm-up

stop SCE	Command the SCE in shutdown mode using the dedicated procedure	see dedicated procedure in RD11

	Note: specifically turn OFF the SCC power lines when the SCE request for it from the TM(5,1) ID 9 keep SCE on to check for correct sorption cooler stopping from its HK TM (valve position).	TC(8,4,112,3h) LCL 63d, 64d, 65d, 66d.
	wait if necessary for bed cool down	
	turn OFF the SCE LCL when observability is no more necessary from PCDU management service	TC(8,4,112,3h) LCL 53d
stop instrument simulation	turn OFF the instruments MTD from PCDU management service	TC(8,4,112,3h) LCL 37d, 59d, 61d (4K) TC(8,4,112,3h) LCL 42d, 43d, then 36d, 11d, 29d (HFI) TC(8,4,112,3h) LCL 51d, 52d, 27d (LFI)
	turn OFF the instruments auxiliary payload from PCDU management service	TC(8,4,112,3h) LCL 13d (FOG MTD) TC(8,4,112,5h) LCL 19d (SREM)
stop the avionics and auxiliary units	turn OFF the STR1 from the ACC service 8, TC_SWITCH_ACMS_UNITS_ONOFF function turn OFF the STR1 LCL from the PCDU management service	TC(8,1,202,1) on unit 3,2 (STR2) TC(8,4,112,3h) LCL 22d
	turn OFF the 1N Cat Bed heaters of RCS-1 branch (confirm 20N HTR OFF)	TC(8,1,245) to set configuration inputs, then TC(8,4,245) to execute (critical command)
	turn OFF the THR/Cat Bed power line A from the PCDU management service	TC(8,4,122,3h) LCL 45d
	turn OFF the SREM from PCDU management service	TC(8,4,122,3h) LCL 19d
	turn OFF the 3 CRS from PCDU management service	TC(8,4,122,3h) LCL 15d, 24d and 25d
turn OFF the ACC	disable the ACC RM by direct TC turn OFF the ACC PM-A by direct TC turn OFF the ACC cold-A and cold-B LCL from PCDU management service	TC(2,1) line 23 and 25 TC(2,1) line 22 and 26d TC(8,4,122,3h) LCL 33d 34d

set-up thermal control for securing the shroud warm-up	load the Phase 1 TCT (see Annex 4) and check it.	TC(8,4,114,18) to load TC(8,5,114) to read back
	verify that all the unit LCL are OFF except for lines 31 and 32 (turn them OFF if any).	

5.5.1.4.10 Phase 03-002: manage shroud warm-up

Synchronisation with shroud warming	wait for criteria about shroud temperature that allow to switch OFF the satellite without thermal risk (specially for external units)	
	turn the satellite OFF according to RD12	
	check satellite shut down	
	shut down satellite EGSE	

5.5.2 Instrument configurations

The sequences described in section 5.5.1 gives the leading procedure for the SCS operations. Detailed operations and configuration of SCS are described in RD11 and referenced in the overall test sequence when relevant.

5.6 Parameters to be measured/Measurement accuracy

5.6.1 SVM parameters

During all test phases the following parameters needed to meet the test objectives shall be measured and recorded:

temperatures

- test thermo-couples acquired by CSL data logger, measurements accuracy shall be less than +/-1°C, frequency of acquisition shall be 1minute except for stabilisation periods (duration 1-2 hours) where SCC panels thermo-couples (#31) shall be acquired every 12s. Monitoring of thermocouples shall be started/recorded as soon as thermocouples are connected to the data logger.
- thermistors acquired by flight CDMU (part of housekeeping)

power

- test heaters supply current and voltage shall be acquired by Thermal Regulation EGSE, measurements accuracy shall be less than 1%, frequency of acquisition shall be 1 minute.
- Currents through all LCL's and HPS acquired by flight CDMU (part of housekeeping)

Status

- TCS heaters status (on/off) acquired by flight CDMU (part of housekeeping)
- MTD heaters status (on/off) acquired by flight CDMU (part of housekeeping)

In addition, the whole SVM essential and non essential housekeeping will be available via the umbilical connection. It will be used to monitor the specimen behaviour during the test and shall be integrally recorded.

5.6.2 PPLM thermal parameters

During all test phases the physical parameters will be measured are recorded as follow:

temperatures

- test sensors defined in AD9, acquired by CSL data logger: measurements accuracy shall be less than +/-1°C for Pt100 and +/-0.5°C for DT470, frequency of acquisition shall be 1minute.

power

- test heaters supply current and voltage shall be acquired by Thermal Regulation and Power Regulation EGSE, measurements accuracy shall be less than 1%, frequency of acquisition shall be 1 minute.

5.6.3 Instrument parameters

Monitoring of instrument parameters during test is described in document RD13.

5.6.4 Facility parameters

Thermal sensors as defined § 4.5.2 shall be acquired and recorded

Monitoring of sensors shall be started/recorded as soon as thermocouples are connected to the data logger.

TRA heaters supply current and voltage shall be acquired by facility: measurements accuracy shall be less than 1%, frequency of acquisition shall be 1 minute.

5.7 Conditions to be verified for test execution

5.7.1 Operations to be performed before test

Before the test, the emissivity of radiators and MLI shall be measured. The zones to be measured as well as the accuracy of the measurement is defined in AD10. This test shall be performed in Cannes facility before transport to CSL.

A healthcheck of the TRA heaters (resistance, insulation) shall be performed before the test

A end to end resistance measurement of the heaters lines between Thermal Regulation EGSE and specimen interface connector shall be performed before the test. This includes

- Central solar array heaters lines (N+R)
- External solar array heaters lines (N+R)
- LVA ring heaters lines (N+R)
- PPLM lines: SCCE and VG3 heaters (N+R)

Functional check out of the specimen will be performed before entering the chamber. A so-called Mini-IST will be performed in Cannes before transport to CSL. Main goal of the Mini-IST is to replay the sequence that will be used during test to check that no failure occurs

Before entering the chamber, a Short Functional Test (SFT) will be run: this SFT is a check of the test sequence run in an accelerated way. In addition, check of test heaters and test sensors shall be performed.

5.7.2 Operations to be performed after test

When exiting the chamber, a reduced functional test of the specimen will be run to check good health of the specimen.

Visual inspection

Check that the MLI have not been dismounted

Check that the sensors have not been de-bonded

After the test, the emissivity of radiators and MLI shall be measured. The zones to be measured as well as the accuracy of the measurement is defined in AD10. This test shall be performed in CSL, as soon as possible after the test.

6. SUCCESS CRITERIA

6.1 SVM success criteria

The test is considered successful if the following criteria are satisfied:

- Test facility requirements are met (to be checked during the Post Test Reviews)
  - interfaces between specimen and test set up on line with the specifications (chapter 4)
  - data recording on line with the specifications (chapter 5.5)

6.2 Instrument functional testing success criteria

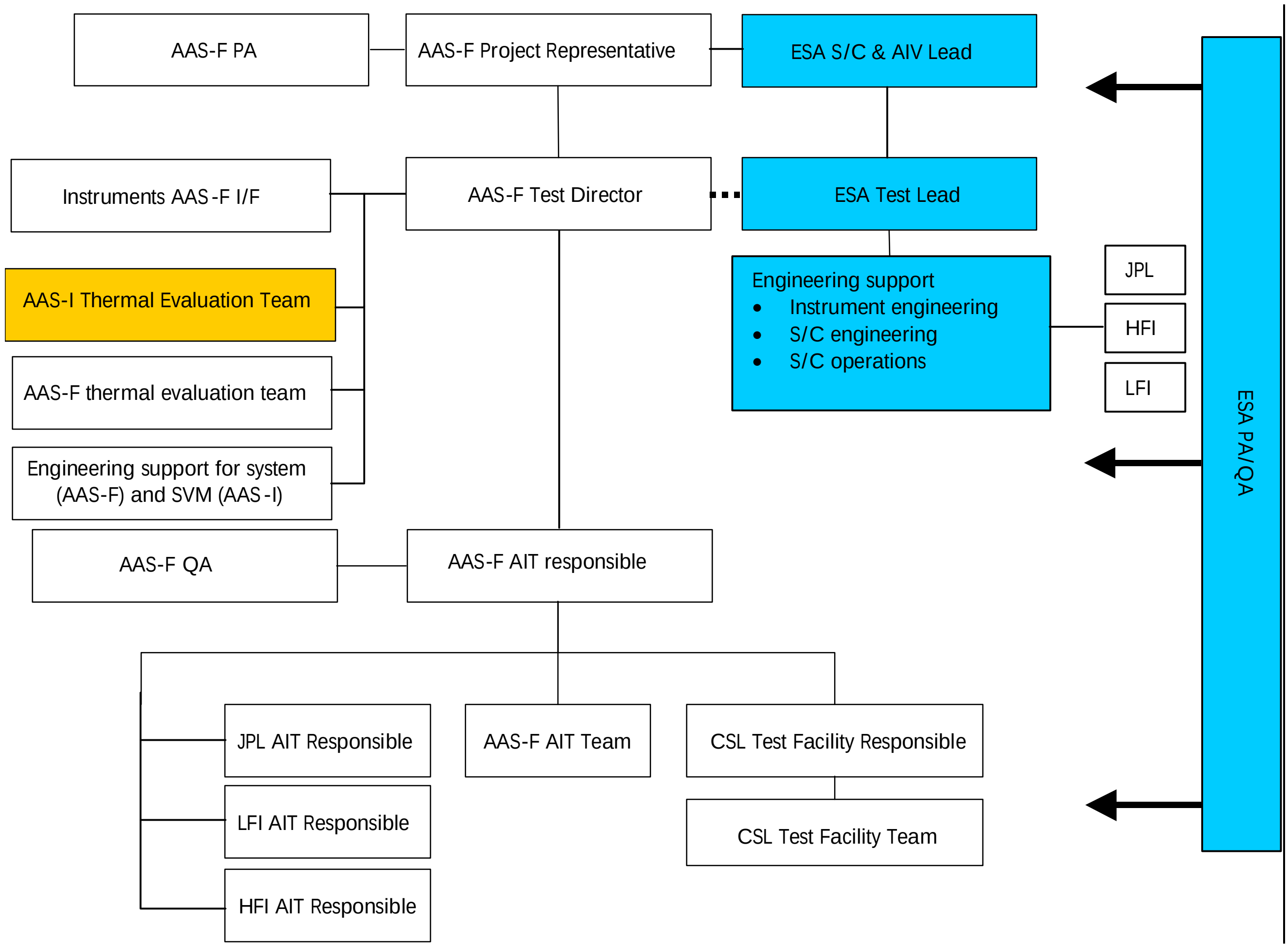
The test is considered successful if the following criteria are satisfied:

- The SCC has operated in Run mode during Phases 2-002/2-005/2-006 with SCC radiator in the [260-280 K] range and the PC3C interface in the [45-60 K] range
- The LVHX2 temperature was below 22.5 K and the LVHX1 temperature was below 19 K during Phases 2-002/2-005/2-006
- The regeneration mode was entered during Phase 2-007.

7. ORGANISATION & RESPONSABILITIES

7.1 Organisation

The overall organisation during the test is as follows:



7.2 Responsibilities

The overall responsibility during the test is as follows:

The responsibilities linked to the test progress shall be mentioned in the AAS-F test leading procedure.

Organization	Responsibility
AAS-F Project Representative D. Montet / P. Armand	Alcatel project interface Represents AAS-F during the test and he is also the I/F point with the ESA representative

Organization	Responsibility
AAS-F PA	AAS-F Project Assurance Manager
AAS-F Test Director L Ouchet	Issue the test specification of the relevant test to be performed Go ahead for the test reviews (TRR, key point, PTR) Single point of contact with the AAS-F Evaluation team concerning the test result status.
ESA S/C and AIV Lead	ESA point of contact I/F with ESA project I/F with AAS-F test director & ESA Test Lead
ESA Test Lead	Go ahead for the test reviews (TRR, key point, PTR) Single point of contact with the ESA engineering support
AAS-I Thermal Evaluation Team Resp. M.Cairola	Evaluate the test data in order to help the test director concerning the "Key point" status. Thermal control of SVM during all phases (limited on structure up to Instruments interfaces)
AAS-F Thermal Evaluation Team Resp. L.OUCHET	Real time assessment of PLM and SVM thermal behaviour Trouble shooting during test
AAS-F AIT responsible	Responsible of the AAS-F AIT Team Single point of contact with the AAS-I AIT team. Issue the leading procedure of all activities Manage all activities done during the test including "key point" meeting. I/F point with the CSL Test Facility Team Responsible I/F point with the HFI AIT Team Responsible I/F point with JPL responsible Organize the Daily meeting Initialize NCR…
AAS-F AIT Team	Realize all S/C AIT activities within the arrival and the leaving Issue of the relevant test procedures Operate the AAS-F GSE Provide the AAS-F test data Issue the AAS-F test report.
Instruments AAS-F I/F J.P. Chambelland	Issue section of the test specification relevant to the instrument AAS-F instrument expert
AAS-F QA	Organize the review (TRR/PTR…)

Organization	Responsibility
	Minute the running meeting (Key point)
CSL Team Responsible	I/F point with the AAS-F AIT responsible
CSL Test Facility Team	Issue the test facility leading procedure (in case of different activities) Issue the relevant test procedures Operate the CSL Test facilities Provide the CSL test data Issue the CSL test report.

7.3 Tasks distribution

7.3.1 General Tasks breakdown

AAS-F is in charge of

- The satellite activities and test management:
- Preparation (tests definition, except for instruments) and execution
- S/C Cleaning, handling, mechanical mounting, electrical checkout, instruments modes set-up.
- Test management (reviews, leading procedure, daily meeting, key points, …)
- Dedicated GSE installation/validations and use
- S/C data analysis.
- Responsible of the test management and for interfaces between the PLANCK satellite and CSL facility.
- Running the PFM test

AAS-I is in charge of

- Support to test specification (specimen configuration, instrumentation…)
- Support to SVM integration
- Follow up of AAE activities
- Test prediction, correlation
- Participation to the test: permanent presence (i.e. 3shift/24 h) is required during SVM critical phases (Phase 1-002, beginning of Phase 2-002, Phase 2-004 to Phase 2-007) in addition to the persons already present on site during the whole test duration (1 thermal engineer + 1 functional engineer)
- Support to test management (reviews, leading procedure, daily meeting, key points, …)

LFI / HFI / JPL is in charge of:

- Preparation, tests definition for SCS instrument
- Dedicated GSE installation/validations and use (I.EGSE)
- Interpretation of instrument performance data
- Provide relevant test data in order to help the test director concerning the "Key point" status.
- Provide assistance in case of major failure of SCS
- Participation to the test: instrument support to provide permanent presence (i.e. 3 shift/24h) during the duration of the sorption cooler operations (currently 9 days TBC), plus support during test preparation (1 person on site, available on call). The phases during which permanent presence is needed are from Ph02-002 to Ph02-007.

CSL is in charge of

- Dedicated GSE installation/validations and use
- Cleaning of every GSE's and Containers under the control of an AAS-F responsible.
- The overall test facility activities
- Preparation of the test facility.
- Running the test facility.

7.3.2 AAS-F thermal team

The AAS-F thermal team will (responsible: L.OUCHET):

- Establish the test specification
- Interfacing with AAS-I, JPL, CSL, ESA teams
- Design and procure test thermal hardware: heaters, fillers, MLI
- Follow up of Integration activities
- Dedicated GSE installation/validations and use
- S/C data analysis.
- Responsible of the test management and for interfaces between the PLANCK satellite and CSL facility.
- Test management (reviews, leading procedure, daily meeting, key points, …)

7.3.3 AAS-F AIT team

The AAS-F AIT team is in charge:

- Realize all S/C AIT activities within the arrival and the leaving
- Interfacing with AAS-I, CSL, JPL AIT teams
- Preparation (tests definition, except for instruments) and execution
- S/C Cleaning, handling, mechanical mounting, electrical checkout, instruments modes set-up.
- Dedicated GSE installation/validations and use
- Provide the AAS-F test data
- Issue the AAS-F test report.

8. DOCUMENTATION

8.1 Documents required before the test

S/C configuration (CIDL, etc)

Test set-up configuration (CIDL, Definition drawings)

Test Set-up validation and calibration status

Test specification

Test predictions

Instrumentation plan (thermal sensors list and location)

Test leading procedure + elementary procedures

8.2 Data acquired during the test

8.2.1 S/C sensors (AAS-F & CSL)

A listing (paper format) will provide the following information (output frequency 1 minute) about each type of specimen sensors:

- Test phase designation
- Acquisition date/time
- Temperature sensor number
- Sensor designation
- Measured value
- Alarms status

An excel file grouping information <Time, Temperature> of all specimen thermal sensors will be updated at a given frequency (1 minute and 12 s for reduced set of sensors and time, see § 5.6.1) and delivered on request to AAS-F thermal team.

An excel file grouping <Time, Power / Amperage> of all specimen heating lines will be updated at a given frequency (1 minute) and delivered on request to AAS-F evaluation team.

In addition, it shall be possible to easily retrieve (in excel file format) the HK data from ACMS and CDMS as described in RD17

8.2.2 Test environment sensors (CSL)

A listing (paper format) will provide the following information (output frequency 1 minute) about test environment sensors:

Test phase designation

Acquisition date/time

For each sensors (temperature, pressure, etc.)

- Sensor number
- Sensor designation
- Measured value
- Alarms status

8.2.3 Instrument sensors

See RD11

8.3 Documents issued after the test

8.3.1 Test Reports

8.3.1.1 Specimen AIT reports (AAS-F)

Test progress description

Contamination control report

Logbook reporting all significant events about specimen

Pictures taken on the specimen in test configuration

Record (CD-ROM) of all acquired data during test

Test measurements devices calibration reports

8.3.1.2 Test environment - CSL

Test progress description

Pictures taken on the test set-up

Logbook reporting all significant events about test set-up

Record (CD-ROM) of all acquired data during test

Test measurements devices calibration reports

8.3.2 Evaluation reports

8.3.2.1 Evaluation report for SVM

The deliverable by AAS-F thermal team are:

Logbook reporting all significant events about specimen thermal control

SVM thermal test report including:

- Thermal performance demonstration
- Test results processing for all phases
- A selection of test set-up Interfaces temperatures useful for specimen behaviour understanding
- Updated SVM TMM and associated flight predictions in case of significant deviation between test predictions and test measurements.

8.3.2.2 Evaluation report for instruments

See RD11

ANNEX1: SCC TMM FOR TEST PREDICTION

BOL 270-52 SCC NOMINAL CASE TMM 345 W

Parameter	Location	Units	Phase 1 Heatup 0-760 s	Phase 2 Desorb 761-1520 s	Phase 3 Cool 1521-2280 s	Phase 4 Absorb 2281-3040 s	Phase 5 Absorb 3041-3800 s	Phase 6 Absorb 3801-4560 s
Therm. Mass	**Inner Bed**	MC_p (J/K)	800	3600	900	670	690	710
	Outer Shell	MC_p (J/K)	720	720	720	720	720	720
Conductance	*(Inner Bed to Outer Shell)*	W/K	0,02	0,03	***	6,53	6,53	6,53
Heat Input	**Inner Bed**	W	153	164	0	50	36	22
	Outer shell	W	0	0	7	7	7	7

**** see attached table**

Notes:

1) The above values are for beginning of life (excluding margin)

2) The total cycle time is 760*6 = 4560 seconds.

3) There are 6 identical beds which are of phase, by one phase width of 760 sec., with respect to each other.

BOL 262-60 SCC HOT CASE TMM 408 W

Parameter	Location	Units	Phase 1 Heatup 0-667 s	Phase 2 Desorb 667-1334 s	Phase 3 Cool 1334-2000 s	Phase 4 Absorb 2001-2667 s	Phase 5 Absorb 2668-3333 s	Phase 6 Absorb 3335-4000 s
Therm. Mass	**Inner Bed**	MC_p (J/K)	800	3600	900	670	690	710
	Outer Shell	MC_p (J/K)	720	720	720	720	720	720
Conductance	*(Inner Bed to Outer Shell)*	W/K	0,02	0,03	***	6,53	6,53	6,53
Heat Input	**Inner Bed**	W	189	190	0	50	36	22
	Outer shell	W	0	0	7	7	7	7

**** see attached table**

Notes:

1) The above values are for beginning of life (excluding margin)

2) The total cycle time is 667*6 = 4002 seconds.

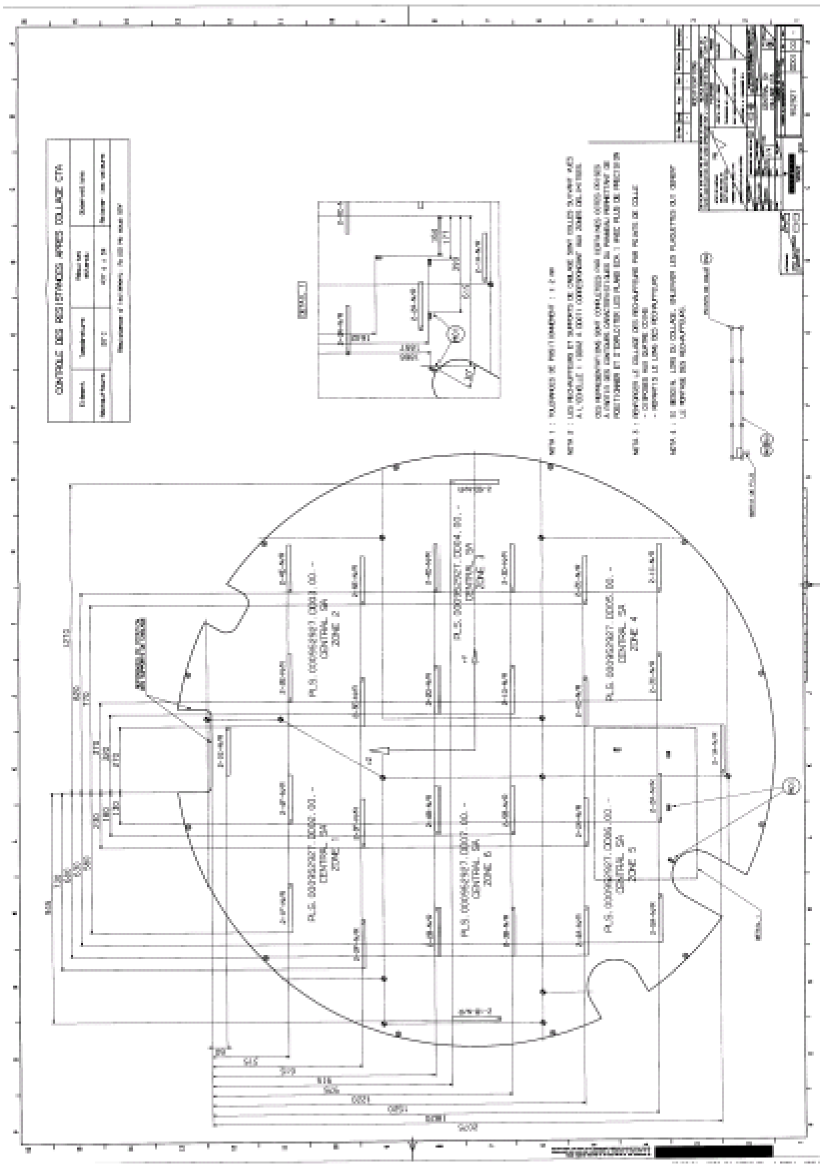
3) There are 6 identical beds which are of phase, by one phase width of 667 sec., with respect to each other.

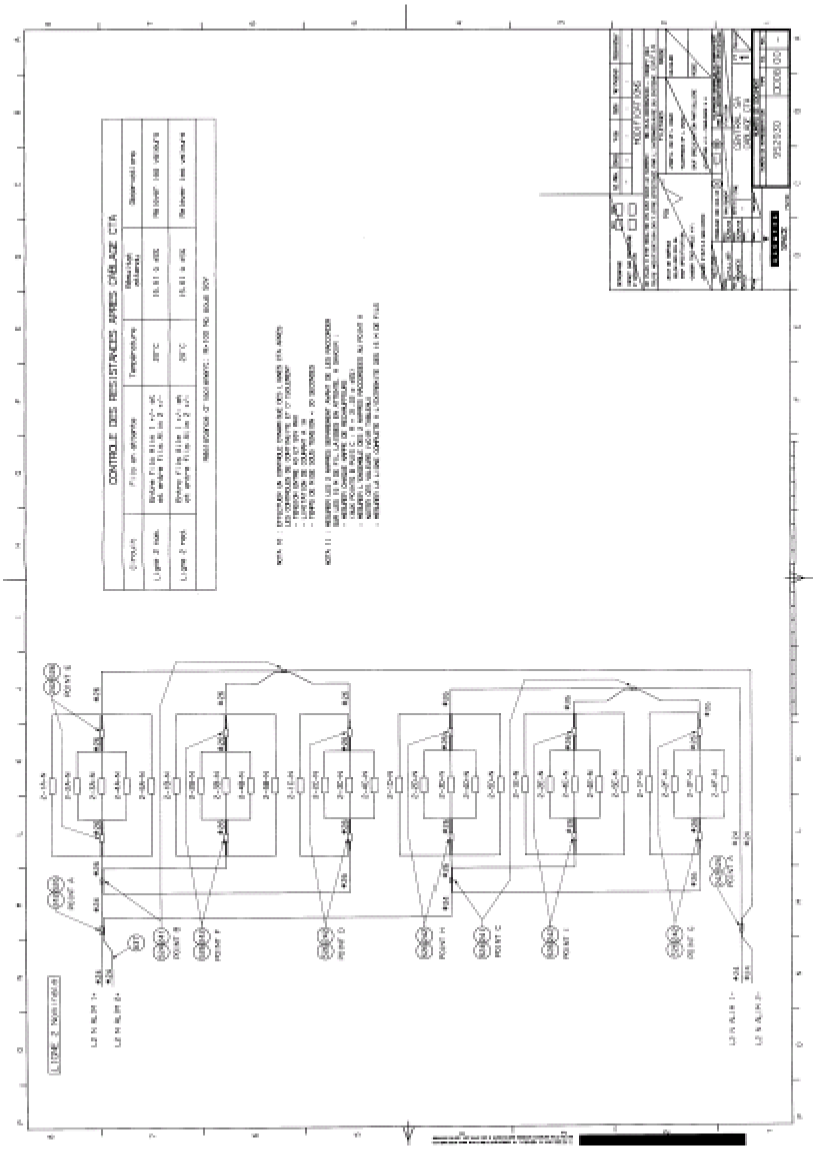
Time	Gas gap Conductance	Time	Gas gap Conductance	Time	Gas gap Conductance	Time	Gas gap Conductance
[s]	[W/K]	[s]	[W/K]	[s]	[W/K]	[s]	[W/K]
0	0,0313	51	1,8118	102	6,2375	153	6,5473
1	0,0314	52	2,0749	103	6,2526	154	6,5480
2	0,0316	53	2,3479	104	6,2673	155	6,5488
3	0,0318	54	2,6215	105	6,2808	156	6,5497
4	0,0319	55	2,8875	106	6,2940	157	6,5505
5	0,0321	56	3,1393	107	6,3069	158	6,5512
6	0,0325	57	3,3734	108	6,3187	159	6,5519
7	0,0329	58	3,5880	109	6,3307	160	6,5525
8	0,0331	59	3,7832	110	6,3420	161	6,5530
9	0,0337	60	3,9600	111	6,3526	162	6,5534
10	0,0344	61	4,2804	112	6,3634	163	6,5536
11	0,0352	62	4,4133	113	6,3728	164	6,5537
12	0,0359	63	4,5360	114	6,3824	165	6,5539
13	0,0368	64	4,6454	115	6,3914	166	6,5541
14	0,0383	65	4,7481	116	6,4003	167	6,5542
15	0,0397	66	4,8422	117	6,4086	**760 or 667**	6,5543
16	0,0414	67	4,9295	118	6,4171	depending on cycle time	

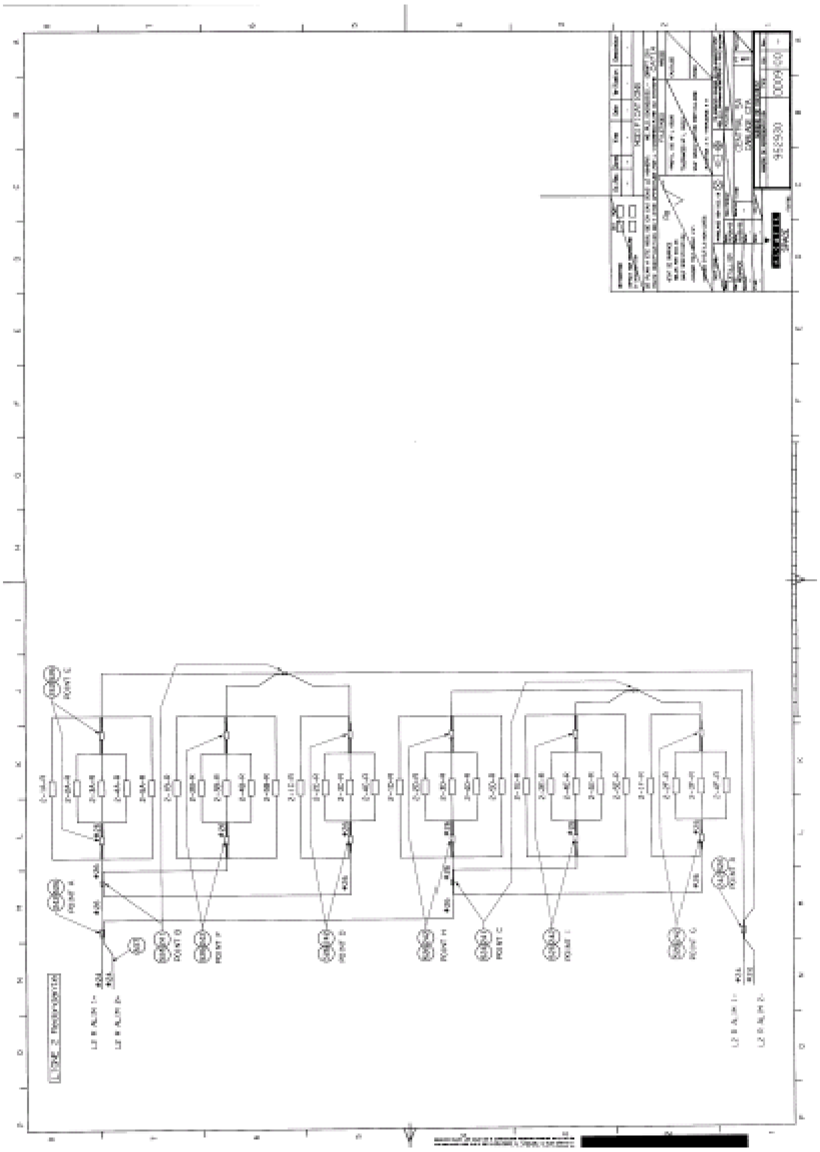
17	0,0434	68	5,0096	119	6,4247
18	0,0459	69	5,0853	120	6,4321
19	0,0487	70	5,1568	121	6,4391
20	0,0519	71	5,2245	122	6,4456
21	0,0558	72	5,2856	123	6,4516
22	0,0602	73	5,3454	124	6,4578
23	0,0653	74	5,4002	125	6,4636
24	0,0709	75	5,4532	126	6,4689
25	0,0775	76	5,5034	127	6,4738
26	0,0849	77	5,5503	128	6,4793
27	0,0934	78	5,5956	129	6,4837
28	0,1029	79	5,6379	130	6,4887
29	0,1137	80	5,6789	131	6,4932
30	0,1258	81	5,7178	132	6,4971
31	0,1393	82	5,7541	133	6,5009
32	0,1546	83	5,7893	134	6,5049
33	0,1716	84	5,8235	135	6,5083
34	0,1908	85	5,8553	136	6,5119
35	0,2123	86	5,8862	137	6,5151
36	0,2366	87	5,9163	138	6,5183
37	0,2641	88	5,9436	139	6,5214

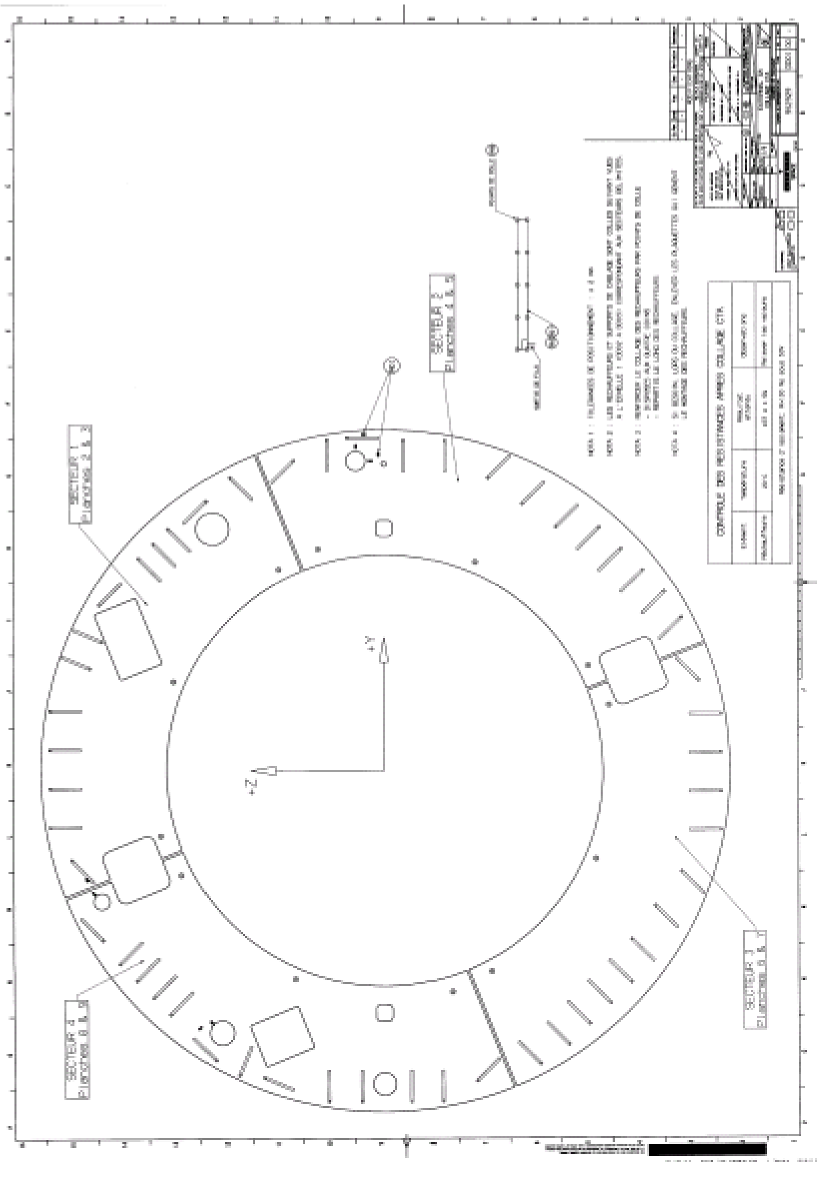
38	0,2956	89	5,9708	140	6,5242
39	0,3317	90	5,9967	141	6,5264
40	0,3735	91	6,0219	142	6,5291
41	0,4224	92	6,0453	143	6,5315
42	0,4799	93	6,0680	144	6,5335
43	0,5482	94	6,0902	145	6,5356
44	0,6297	95	6,1119	146	6,5373
45	0,7276	96	6,1314	147	6,5393
46	0,8556	97	6,1514	148	6,5409
47	0,9855	98	6,1705	149	6,5423
48	1,1518	99	6,1886	150	6,5436
49	1,3457	100	6,2058	151	6,5450
50	1,5667	101	6,2216	152	6,5463

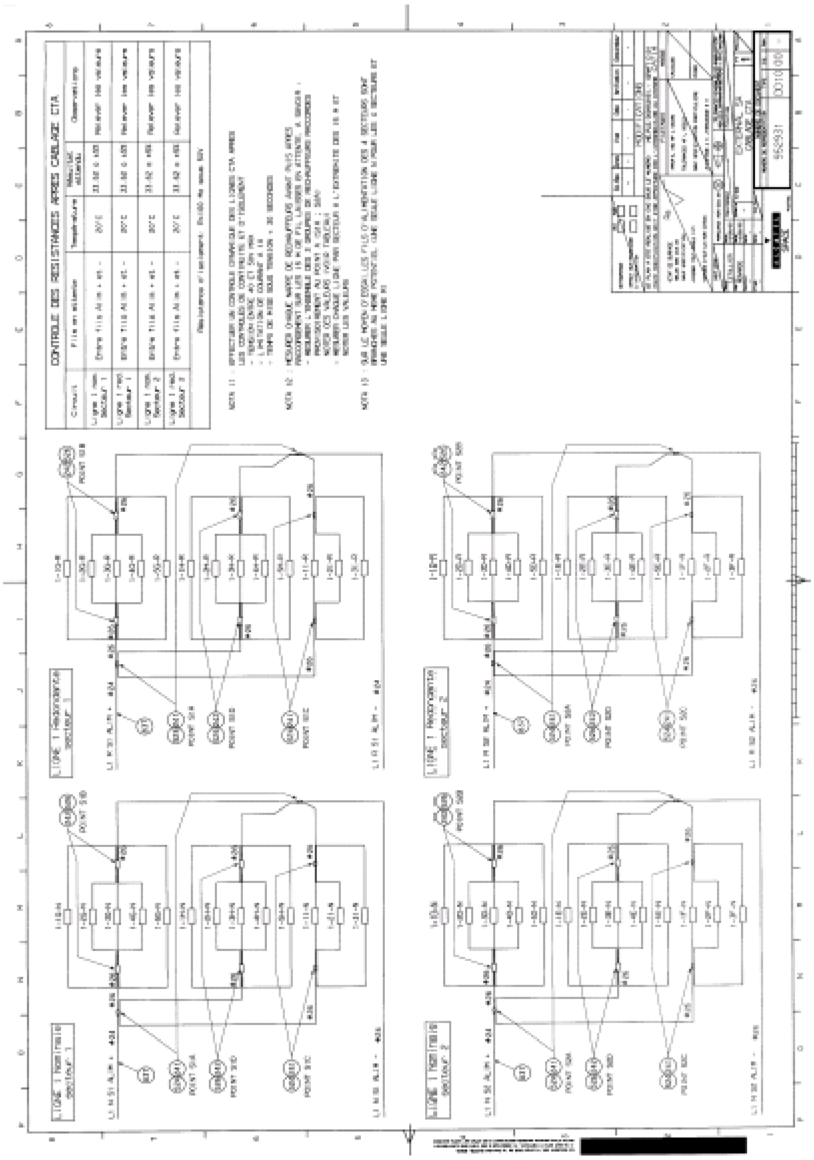
ANNEX 2: TEST HEATING LINES DESIGN

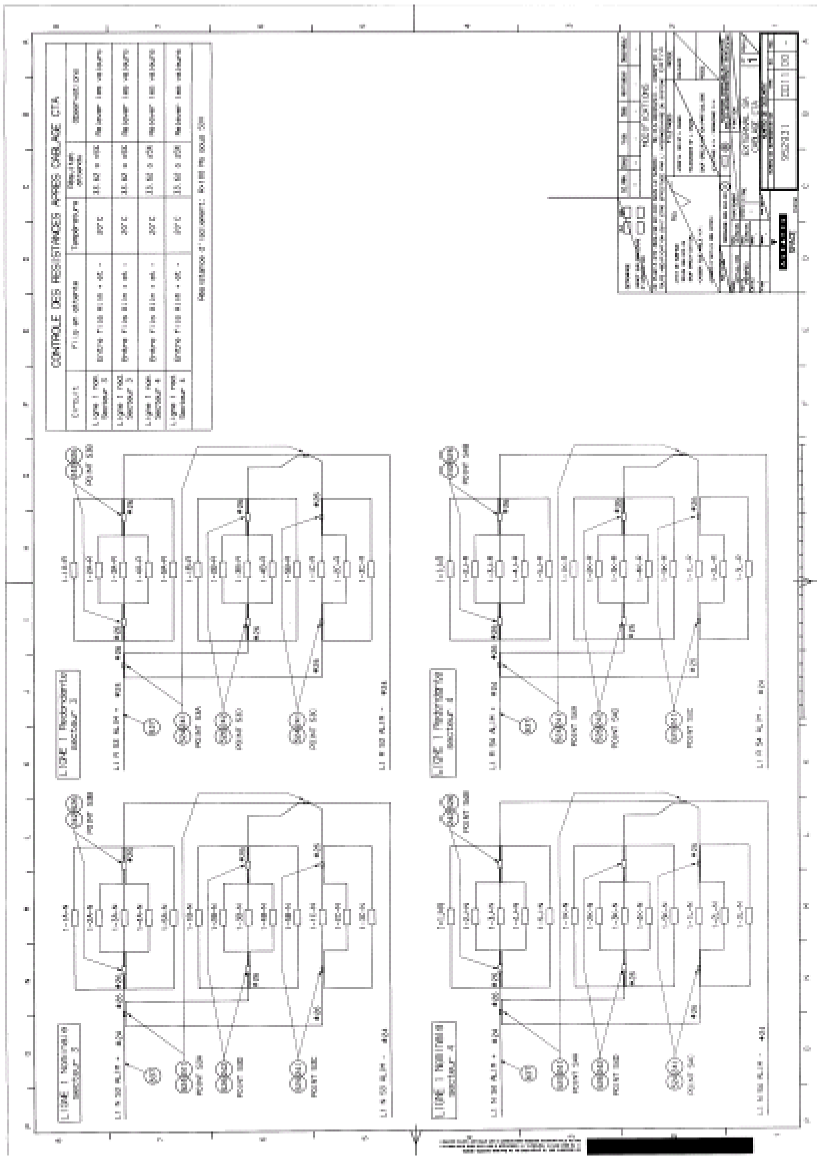


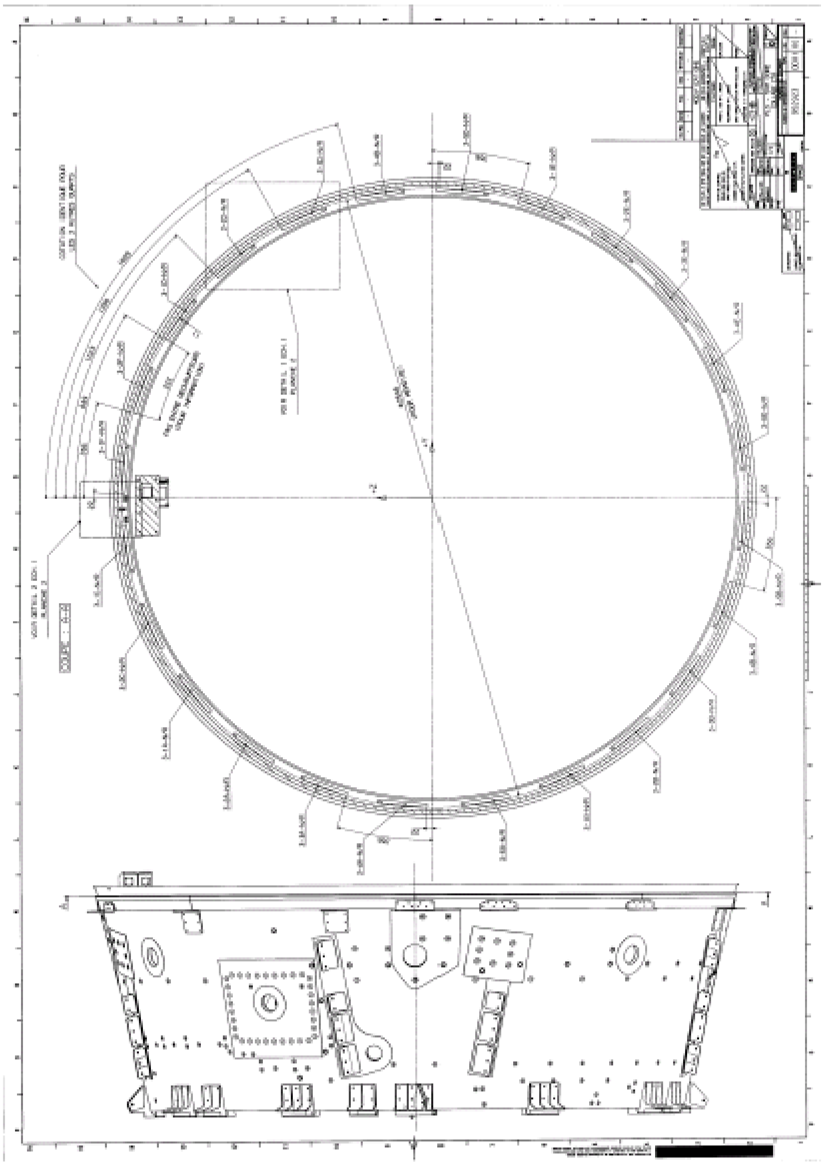


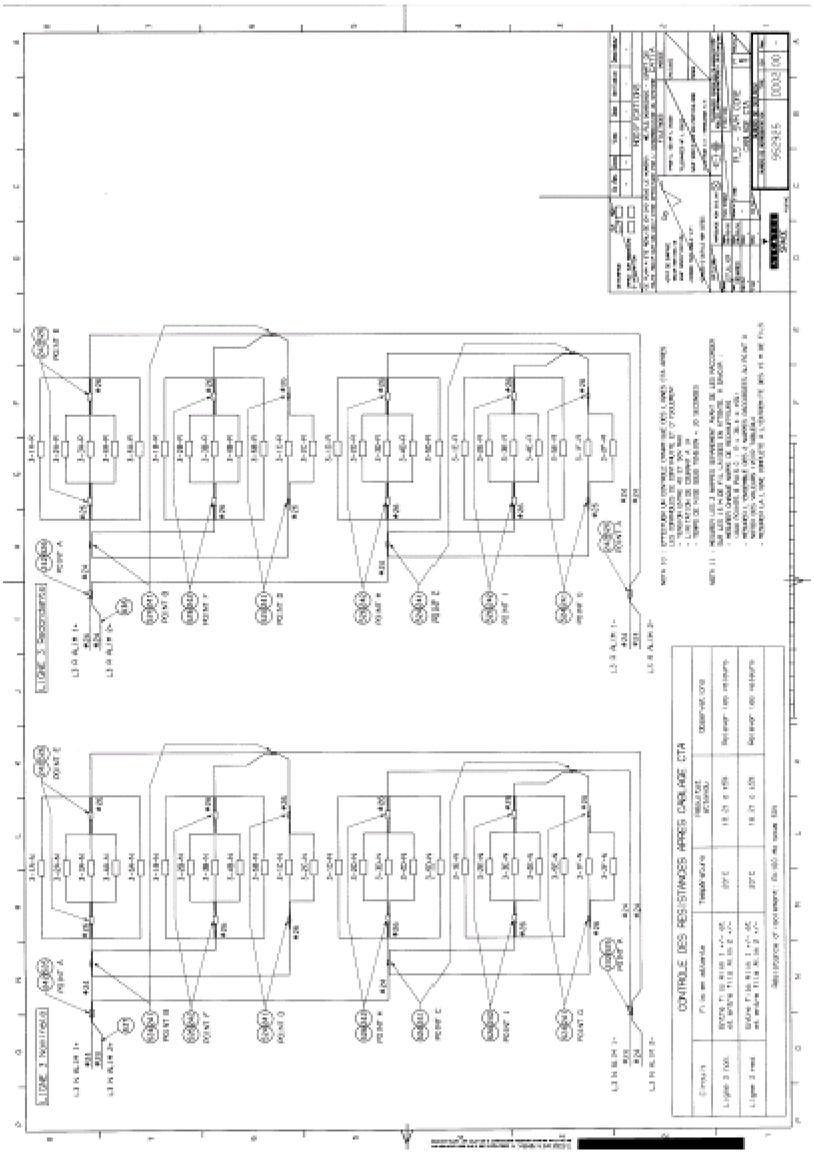












ANNEX 3: SCC COMPRESSOR DISSIPATION DURING REGENERATION (TBD BY ESA)

ANNEX 4: THERMAL CONTROL TABLES (TCT)

Phase 1 TCT:

Nominal heaters control loops					
Heater line	Heater's location	Tmin-on	Tmax-on	Tmin-off	Tmax-off
1	close to STR 1	-29	-26	-29	-26
2	close to STR 2	-29	-26	-29	-26
3	close to DPU-N	-19	-16	-19	-16
4	close to DPU-R	-19	-16	-19	-16
5	close to REU	-19	-16	-19	-16
6	close to CCU, CEU	-18	-15	-18	-15
7	on Heat Pipes	-14	-13	-14	-13
8	on Heat Pipes	-18	-17	-18	-17
9	on Heat Pipes	-13	-12	-13	-12
10	on Heat Pipes	-19	-18	-19	-18
11	on Heat Pipes	-16	-15	-16	-15
12	on Heat Pipes	-17	-16	-17	-16
13	on Heat Pipes	-15	-14	-15	-14
14	HELIUM tanks	-19	-16	-19	-16
15	PAU	-19	-16	-19	-16
16	CRU (4K Reg)	-19	-16	-19	-16
24	on FCV A1A	14	17	14	17
25	on FCV B1A	14	17	14	17
26	on FCV D1A	14	17	14	17
27	on FCV D2A	14	17	14	17
28	on FCV F1A	14	17	14	17
29	on FCV F2A	14	17	14	17
30	on FCV U1A	14	17	14	17
31	on FCV U2A	14	17	14	17
32	on RCS units	19	20	19	20
33	on RCS PIPES	21	22	21	22
34	on RCS PIPES	20	21	20	21
35	close to CAU	-19	-16	-19	-16
36	close to REBA N/R	-29	-26	-29	-26
37	inside BATTERY	1	4	1	4
38	on FCV A1B	14	17	14	17
39	on FCV B1B	14	17	14	17
40	on FCV D1B	14	17	14	17
41	on FCV D2B	14	17	14	17
42	on FCV F1B	14	17	14	17
43	on FCV F2B	14	17	14	17
44	on FCV U1B	14	17	14	17
45	on FCV U2B	14	17	14	17
46	on RCS PIPES	22	23	22	23
47	on RCS PIPES	20	21	20	21
48	on RCS PIPES	20	21	20	21

Redundant heaters control loops					
Heater line	**Heater's location**	**Tmin-on**	**Tmax-on**	**Tmin-off**	**Tmax-off**
55	close to STR 1	-29	-26	-29	-26
56	close to STR 2	-29	-26	-29	-26
57	close to DPU-N	-19	-16	-19	-16
58	close to DPU-R	-19	-16	-19	-16
59	close to REU	-19	-16	-19	-16
60	close to CCU, CEU	-18	-15	-18	-15
61	on Heat Pipes	-14	-13	-14	-13
62	on Heat Pipes	-18	-17	-18	-17
63	on Heat Pipes	-13	-12	-13	-12
64	on Heat Pipes	-19	-18	-19	-18
65	on Heat Pipes	-16	-15	-16	-15
66	on Heat Pipes	-17	-16	-17	-16
67	on Heat Pipes	-15	-14	-15	-14
68	HELIUM tanks	-19	-16	-19	-16
69	PAU	-19	-16	-19	-16
70	CRU (4K Reg)	-19	-16	-19	-16
78	on FCV A1A	14	17	14	17
79	on FCV B1A	14	17	14	17
80	on FCV D1A	14	17	14	17
81	on FCV D2A	14	17	14	17
82	on FCV F1A	14	17	14	17
83	on FCV F2A	14	17	14	17
84	on FCV U1A	14	17	14	17
85	on FCV U2A	14	17	14	17
86	on RCS units	19	20	19	20
87	on RCS PIPES	21	22	21	22
88	on RCS PIPES	20	21	20	21
89	close to CAU	-19	-16	-19	-16
90	close to REBA N/R	-29	-26	-29	-26
91	inside BATTERY	1	4	1	4
92	on FCV A1B	14	17	14	17
93	on FCV B1B	14	17	14	17
94	on FCV D1B	14	17	14	17
95	on FCV D2B	14	17	14	17
96	on FCV F1B	14	17	14	17
97	on FCV F2B	14	17	14	17
98	on FCV U1B	14	17	14	17
99	on FCV U2B	14	17	14	17
100	on RCS PIPES	22	23	22	23
101	on RCS PIPES	20	21	20	21
102	on RCS PIPES	20	21	20	21

Phase 2-002 TCT:

Nominal heaters control loops						
Heater line	Heater's location	Tmin-on	Tmax-on	Tmin-off	Tmax-off	Modified w.r.t. Phase 1
1	close to STR 1	-19	-16	-19	-16	Yes
2	close to STR 2	-29	-26	-29	-26	No
3	close to DPU-N	-9	-6	-9	-6	Yes
4	close to DPU-R	-19	-16	-19	-16	No
5	close to REU	-9	-6	-9	-6	Yes
6	close to CCU, CEU	-9	-6	-9	-6	Yes
7	on Heat Pipes	-14	-13	-14	-13	No
8	on Heat Pipes	-18	-17	-18	-17	No
9	on Heat Pipes	-13	-12	-13	-12	No
10	on Heat Pipes	-19	-18	-19	-18	No
11	on Heat Pipes	-16	-15	-16	-15	No
12	on Heat Pipes	-17	-16	-17	-16	No
13	on Heat Pipes	-15	-14	-15	-14	No
14	HELIUM tanks	-9	-6	-9	-6	Yes
15	PAU	-9	-6	-9	-6	Yes
16	CRU (4K Reg)	-9	-6	-9	-6	Yes
24	on FCV A1A	14	17	14	17	No
25	on FCV B1A	14	17	14	17	No
26	on FCV D1A	14	17	14	17	No
27	on FCV D2A	14	17	14	17	No
28	on FCV F1A	14	17	14	17	No
29	on FCV F2A	14	17	14	17	No
30	on FCV U1A	14	17	14	17	No
31	on FCV U2A	14	17	14	17	No
32	on RCS units	19	20	19	20	No
33	on RCS PIPES	32	33	32	33	Yes
34	on RCS PIPES	28	29	28	29	Yes
35	close to CAU	-9	-6	-9	-6	Yes
36	close to REBA N/R	-29	-26	-29	-26	No
37	inside BATTERY	1	4	1	4	No
38	on FCV A1B	14	17	14	17	No
39	on FCV B1B	14	17	14	17	No
40	on FCV D1B	14	17	14	17	No
41	on FCV D2B	14	17	14	17	No
42	on FCV F1B	14	17	14	17	No
43	on FCV F2B	14	17	14	17	No
44	on FCV U1B	14	17	14	17	No
45	on FCV U2B	14	17	14	17	No
46	on RCS PIPES	35	36	35	36	Yes
47	on RCS PIPES	29	30	29	30	Yes
48	on RCS PIPES	19	20	19	20	Yes

Redundant heaters control loops						
Heater line	Heater's location	Tmin-on	Tmax-on	Tmin-off	Tmax-off	Modified w.r.t. Phase 1
55	close to STR 1	-19	-16	-19	-16	Yes
56	close to STR 2	-29	-26	-29	-26	No
57	close to DPU-N	-9	-6	-9	-6	Yes
58	close to DPU-R	-19	-16	-19	-16	No
59	close to REU	-9	-6	-9	-6	Yes
60	close to CCU, CEU	-9	-6	-9	-6	Yes
61	on Heat Pipes	-14	-13	-14	-13	No
62	on Heat Pipes	-18	-17	-18	-17	No
63	on Heat Pipes	-13	-12	-13	-12	No
64	on Heat Pipes	-19	-18	-19	-18	No
65	on Heat Pipes	-16	-15	-16	-15	No
66	on Heat Pipes	-17	-16	-17	-16	No
67	on Heat Pipes	-15	-14	-15	-14	No
68	HELIUM tanks	-9	-6	-9	-6	Yes
69	PAU	-9	-6	-9	-6	Yes
70	CRU (4K Reg)	-9	-6	-9	-6	Yes
78	on FCV A1A	14	17	14	17	No
79	on FCV B1A	14	17	14	17	No
80	on FCV D1A	14	17	14	17	No
81	on FCV D2A	14	17	14	17	No
82	on FCV F1A	14	17	14	17	No
83	on FCV F2A	14	17	14	17	No
84	on FCV U1A	14	17	14	17	No
85	on FCV U2A	14	17	14	17	No
86	on RCS units	19	20	19	20	No
87	on RCS PIPES	32	33	32	33	Yes
88	on RCS PIPES	28	29	28	29	Yes
89	close to CAU	-9	-6	-9	-6	Yes
90	close to REBA N/R	-29	-26	-29	-26	No
91	inside BATTERY	1	4	1	4	No
92	on FCV A1B	14	17	14	17	No
93	on FCV B1B	14	17	14	17	No
94	on FCV D1B	14	17	14	17	No
95	on FCV D2B	14	17	14	17	No
96	on FCV F1B	14	17	14	17	No
97	on FCV F2B	14	17	14	17	No
98	on FCV U1B	14	17	14	17	No
99	on FCV U2B	14	17	14	17	No
100	on RCS PIPES	35	36	35	36	Yes
101	on RCS PIPES	29	30	29	30	Yes
102	on RCS PIPES	19	20	19	20	Yes

Phase 2-004 TCT:

Nominal heaters control loops						
Heater line	Heater's location	Tmin-on	Tmax-on	Tmin-off	Tmax-off	Modified w.r.t. Phase 2-002
1	close to STR 1	-19	-16	-19	-16	No
2	close to STR 2	-19	-16	-19	-16	Yes
3	close to DPU-N	-9	-6	-9	-6	No
4	close to DPU-R	-19	-16	-19	-16	No
5	close to REU	-9	-6	-9	-6	No
6	close to CCU, CEU	-9	-6	-9	-6	No
7	on Heat Pipes	-14	-13	-14	-13	No
8	on Heat Pipes	-18	-17	-18	-17	No
9	on Heat Pipes	-13	-12	-13	-12	No
10	on Heat Pipes	-19	-18	-19	-18	No
11	on Heat Pipes	-16	-15	-16	-15	No
12	on Heat Pipes	-17	-16	-17	-16	No
13	on Heat Pipes	-15	-14	-15	-14	No
14	HELIUM tanks	-9	-6	-9	-6	No
15	PAU	-9	-6	-9	-6	No
16	CRU (4K Reg)	-9	-6	-9	-6	No
24	on FCV A1A	14	17	14	17	No
25	on FCV B1A	14	17	14	17	No
26	on FCV D1A	14	17	14	17	No
27	on FCV D2A	14	17	14	17	No
28	on FCV F1A	14	17	14	17	No
29	on FCV F2A	14	17	14	17	No
30	on FCV U1A	14	17	14	17	No
31	on FCV U2A	14	17	14	17	No
32	on RCS units	19	20	19	20	No
33	on RCS PIPES	32	33	32	33	No
34	on RCS PIPES	28	29	28	29	No
35	close to CAU	-9	-6	-9	-6	No
36	close to REBA N/R	-29	-26	-29	-26	No
37	inside BATTERY	1	4	1	4	No
38	on FCV A1B	14	17	14	17	No
39	on FCV B1B	14	17	14	17	No
40	on FCV D1B	14	17	14	17	No
41	on FCV D2B	14	17	14	17	No
42	on FCV F1B	14	17	14	17	No
43	on FCV F2B	14	17	14	17	No
44	on FCV U1B	14	17	14	17	No
45	on FCV U2B	14	17	14	17	No
46	on RCS PIPES	35	36	35	36	No
47	on RCS PIPES	29	30	29	30	No
48	on RCS PIPES	19	20	19	20	No

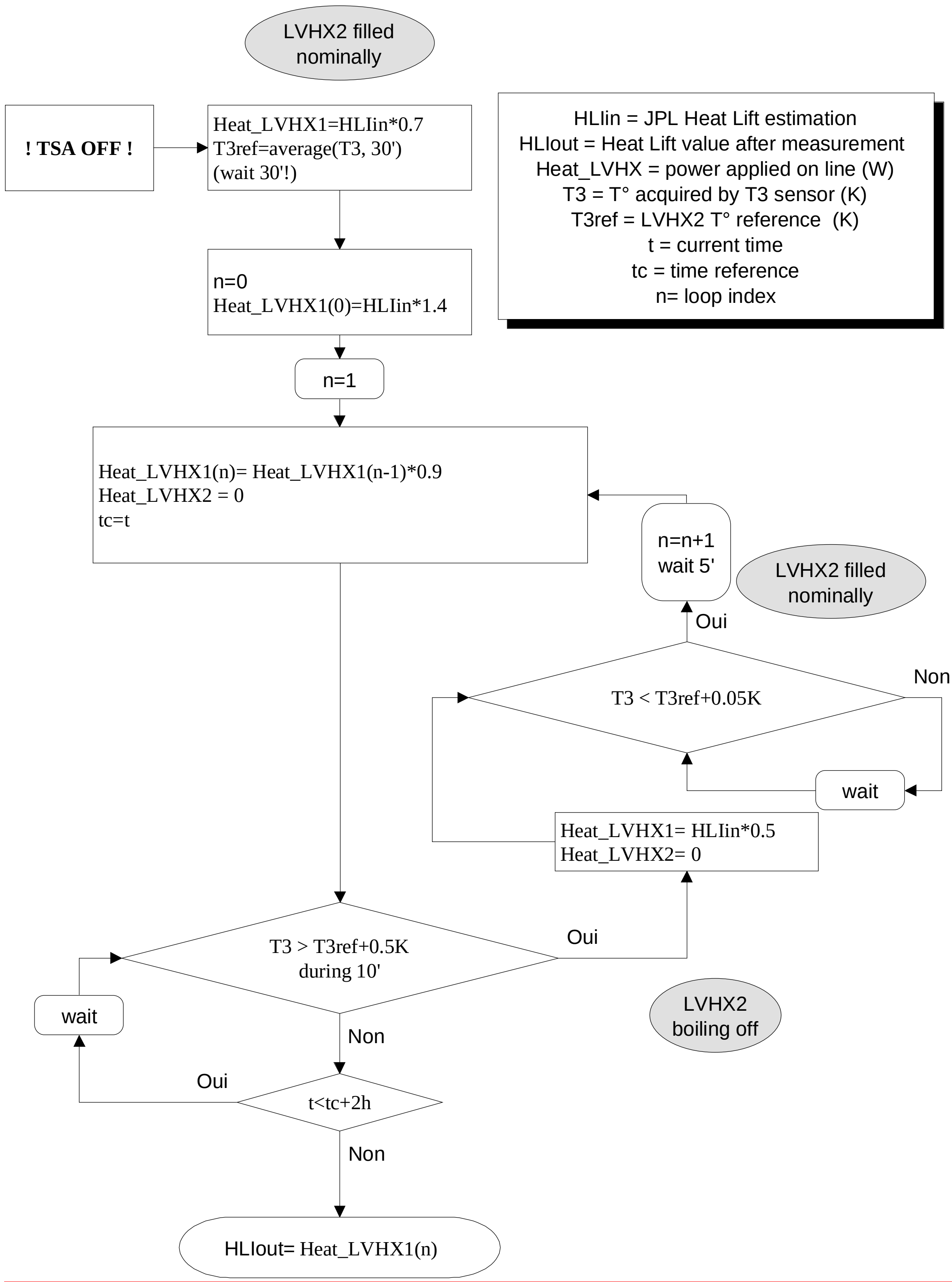
Redundant heaters control loops						
Heater line	Heater's location	Tmin-on	Tmax-on	Tmin-off	Tmax-off	Modified w.r.t. Phase 1
55	close to STR 1	-19	-16	-19	-16	No
56	close to STR 2	-19	-16	-19	-16	Yes
57	close to DPU-N	-9	-6	-9	-6	No
58	close to DPU-R	-19	-16	-19	-16	No
59	close to REU	-9	-6	-9	-6	No
60	close to CCU, CEU	-9	-6	-9	-6	No
61	on Heat Pipes	-14	-13	-14	-13	No
62	on Heat Pipes	-18	-17	-18	-17	No
63	on Heat Pipes	-13	-12	-13	-12	No
64	on Heat Pipes	-19	-18	-19	-18	No
65	on Heat Pipes	-16	-15	-16	-15	No
66	on Heat Pipes	-17	-16	-17	-16	No
67	on Heat Pipes	-15	-14	-15	-14	No
68	HELIUM tanks	-9	-6	-9	-6	No
69	PAU	-9	-6	-9	-6	No
70	CRU (4K Reg)	-9	-6	-9	-6	No
78	on FCV A1A	14	17	14	17	No
79	on FCV B1A	14	17	14	17	No
80	on FCV D1A	14	17	14	17	No
81	on FCV D2A	14	17	14	17	No
82	on FCV F1A	14	17	14	17	No
83	on FCV F2A	14	17	14	17	No
84	on FCV U1A	14	17	14	17	No
85	on FCV U2A	14	17	14	17	No
86	on RCS units	19	20	19	20	No
87	on RCS PIPES	32	33	32	33	No
88	on RCS PIPES	28	29	28	29	No
89	close to CAU	-9	-6	-9	-6	No
90	close to REBA N/R	-29	-26	-29	-26	No
91	inside BATTERY	1	4	1	4	No
92	on FCV A1B	14	17	14	17	No
93	on FCV B1B	14	17	14	17	No
94	on FCV D1B	14	17	14	17	No
95	on FCV D2B	14	17	14	17	No
96	on FCV F1B	14	17	14	17	No
97	on FCV F2B	14	17	14	17	No
98	on FCV U1B	14	17	14	17	No
99	on FCV U2B	14	17	14	17	No
100	on RCS PIPES	35	36	35	36	No
101	on RCS PIPES	29	30	29	30	No
102	on RCS PIPES	19	20	19	20	No

ANNEX 5 PROCEDURE TO MEASURE COOLING POWER OF SCS

JPL will estimate the total heat lift (named HLI) which will be used as input to iterative measurement, as explained in next diagram.

The TSA must be OFF during the procedure.

JPL temperature sensor T3 is nominally used for measurement. In case of failure, T3 can be replaced by T4. In case of T4 failure, AAS test sensors Di421&Di422 can be used. All these sensors acquisitions will be recorded during procedure. If any sensor failure occurs during measurement, the procedure can be continued with back-up sensors with adequate adaptations (T3ref becomes T4ref for instance).


LVHX2 filled nominally
! TSA OFF !
Heat_LVHX1=HLIin*0.7
T3ref=average(T3, 30')
(wait 30'!)
HLIin = JPL Heat Lift estimation
HLIout = Heat Lift value after measurement
Heat_LVHX = power applied on line (W)
T3 = T° acquired by T3 sensor (K)
T3ref = LVHX2 T° reference (K)
t = current time
tc = time reference
n= loop index
n=0
Heat_LVHX1(0)=HLIin*1.4
n=1
Heat_LVHX1(n)= Heat_LVHX1(n-1)*0.9
Heat_LVHX2 = 0
tc=t
n=n+1
wait 5'
LVHX2 filled nominally
Oui
T3 < T3ref+0.05K
Non
wait
Heat_LVHX1= HLIin*0.5
Heat_LVHX2= 0
T3 > T3ref+0.5K
during 10'
Oui
LVHX2 boiling off
wait
Non
Oui
t<tc+2h
Non
HLIout= Heat_LVHX1(n)